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INTRODUCTION

This listing of the Johnson Space Center's scientific and technical publi-
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OFFICE OF THE DIRECTOR

1. Cohen, Aaron: Space Technology Today. <u>Journal of Vacuum Science and Technology</u>, Vol. A4, No. 3, pp. 263-267, May/June 1986.

   Technologies developed in support of our civil space program have progressed considerably over the 25-year life of the National Aeronautics and Space Administration. Many of these advances are the result of a continuing increase in knowledge relative to the environments of space and the utilization of these previously designated hostile elements to gain design application advantages. Much more significant utilization of the environmental elements is forecast as space research and commercial goals and objectives begin to gain momentum. Challenges in design of our Shuttle system and the next major goal, the Space Station, are significant and will result in greater utilization of the microgravity and vacuum of space as a benefit to research and operational goals.

2. Cohen, Aaron: Use of Automation and Robotics for the Space Station. Presented at the International Society for Optical Engineering, October 26, 1986, Cambridge, Massachusetts.

   To ensure maximum Space Station productivity and utility, operating personnel must be freed from chores that can be done by machines to devote their time to customer and user needs that cannot be done by machines. Technological advances in a variety of disciplines, collectively called automation and robotics, offer the potential of revolutionizing our approach to space operations. Much of the knowledge gained and the advances made will be transferrable to terrestrial applications to increase the productivity of the nation's economy as a whole. This paper provides an overview and a summary of the various possible applications and benefits of automation and robotics technology, both near-term and long-term to the Space Station system. Also included are remarks relevant to NASA's approach to fostering the development of the needed technologies and views on the benefits to the Nation's economy.

3. Cohen, Aaron; and Erickson, Jon D.: Automation and Robotics. Presented at the 2nd AIAA Space Station Symposium, August 19-20, 1986, Washington, D.C.

   The progress of advancing the technologies of automation and robotics on the Space Station is summarized. NASA's strategy and Space Station design considerations are described. Important considerations such as identification of candidates for the initial station, provisions for incorporation of advanced technology in an evolutionary station, the flight telerobotic system, and life cycle costing are discussed.

FLIGHT CREW OPERATIONS DIRECTORATE

1. Hauck, Frederick; and Gardner, Dale: Space Salvage: A Report on Shuttle Mission STS 51-A. Presented at the Society of Flight Test Engineers 17th Annual Symposium, August 1986, Arlington, Virginia. Published in <u>Proceedings</u>.

    Development, testing, and onorbit employment of hardware used in the STS 51-A salvage of two HS-376 series satellites are discussed. Factors in the successful mission included simulation and procedural preparations, orbiter sensor optimization, night stationkeeping techniques, and EVA satellite stabilization tasks, utilizing the manned maneuvering unit (MMU).

MISSION OPERATIONS DIRECTORATE

1. Bates, William V., Jr.; and Holliman, Charles T.: MCC Flight Operations Automation of STS Orbiter Systems Monitoring. Presented at the 23rd Space Congress, April 22-25, 1986, Cocoa Beach, Florida.

   As the Orbiter flight rate increases and the program moves towards an operational technical/scientific national resource, the challenge to provide quality support, products, and crew training will be extremely difficult with existing approaches and facilities. Several efforts are in work to alleviate the workload being imposed on the present highly trained staff by applying automation techniques, especially in the telemetry monitoring and analysis areas. A phased incorporation of state-of-the-art, multi-tasking, distributed workstations with software defined and developed by operations personnel is well under way. A new concept of user developed prototypes that are evaluated in parallel with present centralized monitoring systems and then phase-incorporated into the mode of operations has been established. Intense involvement of users and developers from concept inception through prototype delivery assures a high degree of evaluation, refinement, and acceptance.

2. Highland, Fred (IBM); and Olszewski, Oscar W. (JSC): An Expert System for Space Shuttle Flight Control. Technical Directions, Vol. 12, No. 3/4, pp. 35-42, 1986.

   Design, application development, and status are reviewed, including the entry navigation flight control task which the expert system performs; design of the expert system software used for prototype development; the development approach used to create the knowledge base; user interface for the candidate application; the results obtained from the prototype; and the conclusions drawn from this reasearch.

3. Hughes, Frank E.: Flight Training for Space Shuttle Missions. Presented at the 1986 Society for Computer Simulation Multiconference, January 23-24, 1986, San Diego, California.

   The training for Space Shuttle flights is totally dependent on computer generated cockpit simulations and integrated simulations between the simulators and the Mission Control Center (MCC). These simulations form a complex set of dress rehearsals of the actual space flight allowing the participants to address problems in a real world situation and utilize problem solving rationale just as they will be called upon to do during the real flight. The benefits of this type of training have been demonstrated during the flights of the Shuttle. This system of integrated simulation and training will be continued in the future using even more intricate man-machine interactions required to initialized, control, and operate it.

4. Kimball, Marilyn W. (JSC); and Minter, Larry A. (Rockwell Shuttle Operations Company): Evaluation of an Expert System Development Tool Kit from a Non-Programming, User's Viewpoint. Presented at the ROBEXS' 86, June 5-6, 1986, Houston. Texas. Published in <u>Proceedings</u>.

Current ground control mission operations functions performed for Space Shuttle flights are manpower intensive. The operations community is working toward streamlining this function by developing prototype applications on distributed workstations to monitor, filter, limit sense, and manipulate real time vehicle data. A further step will be to incorporate the expertise of the flight control personnel into the distributed workstations. The fuel cell monitoring automation prototype is being conducted to assess expert system development technology for use within the mission operations community. All of the operations procedures are fully documented and verified (design, simulation, and mission data), and the ground flight controllers (domain experts) fully understand the decision-making reasoning. We believe the flight controllers can build their own expert system applications without the use of knowledge engineers if they are given a computer with an easy-to-use expert system development.

5. Stark, George E. (Mitre Corporation); and Shooman, Martin L. (Polytechnic Institute of New York): A Comparison of Software Reliability Models Based on Field Data. Presented at the ORSA/TIMS Joint National Meeting, October 27-29, 1986, Miami, Florida.

This paper presents a comparison of three widely used software reliability models based on realtime software developed for the Shuttle Mission Simulator at NASA's Johnson Space Center. The realtime code contains approximately 365,000 FORTRAN source lines in 956 modules and 275,000 lines of Assembly code distributed among 686 modules. The simulator provides high-fidelity training for astronauts and ground controllers for Space Shuttle missions. The Littlewood and Verrall, Musa, and Shooman models are compared. Factors stressed are ease of data collection and model implementation, ease of interpretation, and prediction accuracy.

ENGINEERING DIRECTORATE

1. Moser, Thomas; and Erickson, Jon D. (JSC): The Evolution of Automation and Robotics in Manned Spaceflight. Presented at the 37th International Astronautical Federation Congress, October 4-11, 1986, Innsbruck, Austria.

    The paper briefly delineates the evolution of automation on all manned spacecraft up to and including the Space Shuttle. A concept for increasing automation and robotics from the current Shuttle remote manipulator system (RMS) to an autonomous system is presented. The Space Station, in the role as a satellite servicing facility and a space transportation mode, will require that many functions be performed by intelligent machines because of limited manpower resources. Systems serviced must be designed to accomodate such systems. The paper addresses the plans for standardizing components for satellite servicing and compares the enchanced capabilities with manual performance. Considering a lunar base, manned GEO stations, and perhaps a manned mars mission, the paper projects the services which could be required to check out, maintain, and refuel orbital transfer vehicles (OTV), orbital maneuvering vehicles (OMV), and other spacecraft.

Crew and Thermal Systems Division

1. Bingham, Paul E. (Martin Marietta Denver Aerospace): Enhanced Performance for the Manned Maneuvering Unit. Presented at the 37th International Astronautical Congress, October 8, 1986, Innsbruck, Austria. Published in <u>Acta Astronautica</u>, Vol. 16.

   The manned maneuvering unit (MMU) is described, with an overview of the controls and physical features and a discussion of the propulsion and electrical systems. The capabilities of the MMU are briefly described, including translational and rotational acceleration rates and attitude hold. Current work on a propellant tank kit (PTK), which will provide sufficient propellant storage capability that the MMU with PTK will have twice the previous delta velocity capability, thus doubling the MMU's maneuvering ability, is shown. Results of development testing in the NASA/JSC Weightless Environment Test Facility are included. Proposed space operations resulting from the enhancement include erecting space structures from the Space Shuttle, assembling and maintaining Space Station, and rescue-transfer of astronauts.

2. Chow, L. C. (University of Kentucky); and Parish, Richard C. (JSC): Condensation Heat Transfer in a Microgravity Environment. Presented at the AIAA 24th Aerospace Sciences Meeting, January 6-9, 1986, Reno, Nevada.

   A description of the condensation heat transfer process in a microgravity environment is given. A review of the literature is also reported. Two mechanisms for condensate removal are analyzed by looking into two problems: (1) film condensation on a flat porous plate with the condensate being removed by suction at the wall, and (2) an analytical prediction of the heat transfer coefficient for condensing annular flows with the condensate film driven by the vapor shear. It is concluded that both suction and vapor shear can effectively drain the condensate to ensure continuous operation of the condensers operated in a microgravity environment. It is recommended that zero-g flight experiments be carried out to verify the prediction made in the present paper.

3. Heizer, B. L.; Goo, S. D.; Rhodes, G. D.; Thoreson, Douglas W. (Boeing Aerospace Company): Environmental Avoidance for Steerable Space Station Radiators. Presented at the ICES SAE Conference, July 14-16, 1986, San Diego, California.

   Future large space structures, such as the Space Station, will have high power dissipation and long life requirements which dictate the need for steerable radiators. With the advent of a rotary coupling that enables positioning radiators to a desired environment, this need can be met. In order to perform this task, the coupling requires a control system. Several different concepts have been evaluated for this application. Sensors located on the solar arrays or rotating sensors located on the radiators to measure solar radiation, software control that compares measured flux with expected flux, and software control using Space Station guidance, navigation and control (GN&C) computer inputs were considered.The most effective system was found to be one that uses information from the GN&C computer to determine the

current and required radiator position. Once in operation, updating the programming is not required for growth. Fault detection, replacement, and repair operations are less complex than for the sensor systems. This software control system was selected for the flight design.

4. Kutschker, Alfred; Taylor, Robert M. (Leeds and Northrup Company); and Cusick, Robert J. (JSC): Design of an Oxygen Sensor with Automatic Self-Testing and Calibration Capability. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California. Published in Aerospace Environmental Systems: Proceedings of the 16th ICES Conference, p. 177, July 1986.
   Leeds and Northrup Company is developing a long life oxygen (O_2) sensor for monitoring cabin atmospheric O_2 pressure in future spacecraft. This paper presents the sensor design concept and tradeoffs and describes the various methods to calibrate and verify proper operation. The zirconia sensor incorporates both potentiometric and coulometric measuring techniques operating simultaneously and independently of each other. Coulometric measurements are used to calculate the cabin sample O_2 pressure without comparison to any reference state, thereby making it possible to calibrate the sensor without consumables. The use of independent measurements permits the verification of results obtained with either technique and thus greatly enhances confidence in the results. In addition, the design includes fault diagnostics which takes corrective action if a fault occurs. A breadboard sensor has been constructed and is being operated continuously in the laboratory. Preliminary test results are presented.

5. Lawson, B. Michael (JSC); Roebelen, George J.; Bayes, Stephen A. (Hamilton Standard): Regenerable Non-Venting Thermal Control Subsystem for Extravehicular Activity. Presented at the 16th Intersociety Conference on Environmental Systems, July, 1986, San Diego, California. Published in Aerospace Environmental Systems: Proceedings of the 16th ICES Conference, pp. 345-355, July 1986.
   With the advent of manned spacecraft opportunities requiring routine and complex extravehicular activities (EVA), a new concept for heat rejection is mandatory in order to realize maximum mission productivity. An optimum extravehicular mobility unit (EMU) thermal control subsystem must be capable of successful operation without requiring expendables or introducing contaminants into the environment, conform to reasonable size limitations, and be readily regenerable. This paper describes the development of two thermal control subsystems, one capable of being integrated with the existing Shuttle Orbiter EMU to provide a 3-hour non-venting heat rejection capacity within the EMU mission profile, and a second capable of providing the entire heat rejection capacity required for a potential 8-hour Space Station EVA.

6. Meyer, D. Paul; Thompson, Joe J.; and Olson, R. L. (Boeing Aerospace Company): Space Station EVA Using a Maneuvering Enclosure Unit. Presented at the 16th Intersociety Conference on Environmental Systems, July 16, 1986, San Diego, California.

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7. Parish, Richard C.: Microgravity Fluid Management in Two-Phase Thermal
   Systems. Presented at the Microgravity Fluids Management Symposium,
   September 9-10, 1986, Cleveland, Ohio.

   The Thermal Systems Branch in the Crew and Thermal Systems Division
   at JSC currently has several programs underway to enhance the under-
   standing of two-phase fluid flow characteristics. The objective of
   one of these programs is to design, fabricate, and fly a two-phase
   flow regime mapping experiment in the Shuttle vehicle middeck. Such
   an experiment should aid in defining the types of liquid/vapor dynamic
   interactions and attendent pressure drops which will be present under
   microgravity conditions. Another program, sponsored by OAST, will in-
   volve the testing of a two-phase thermal transport loop aboard the KC-
   135 reduced gravity aircraft. The objective of that effort will be to
   identify system implications of pressure drop variation as a function
   of the flow quality and flow regime present in a representative ther-
   mal system. Information from each of these experiments will be used
   in designing a flight test article of the prototype thermal bus system
   which is to be scheduled to fly as a payload aboard the Shuttle vehi-
   cle. These experiment results will ultimately allow the Space Station
   thermal management system to be designed with engineering confidence
   and with increased operational efficiency.

8. Powell, F. T.; Wynveen, R. A. (Life Systems, Inc.); and Lin, C. (JSC):
   Environmental Control/Life Support Technologies for Advanced Manned
   Space Missions. Presented at the 16th Intersociety Conference.on En-
   vironmental Systems, July 14-16, 1986, San Diego, California. SAE Pa-
   per No. 860994.

   A NASA sponsored program is under way to establish an environmental
   control/life support system (ECLSS) research and development plan for
   a cost-effective technology to be available when advanced manned space
   missions are being defined and preliminary designs established. Pre-
   liminary results of this program are presented, including scope of the
   defined ECLSS, review of the ECLSS on prior missions, status of the
   ECLSS, definition of projected advanced manned missions, requirements
   for advanced missions, unique mission drivers, and planning the ECLSS.

9. Putnam, David F.; Colombo, Gerald V. (Umpqua Research Company); and
   Chullen, Cinda (JSC); Pre- and Post-Treatment Techniques for Space-
   craft Water Recovery. Presented at the 16th Intersociety Conference
   on Environmental Systems, July 16, 1986, San Diego, California. SAE
   Paper No. 860982.

   Waste water pre-treatment and recovered water post-treatment tech-
   niques are essential for Space Station life support in order to
   achieve the quality required of recycled water. This paper identifies
   methods of pre- and post-treatment applicable to spacecraft water re-
   covery by distillation. The results of laboratory investigations show
   that oxidizers, which typically have been components of urine pre-
   treatment formulas, produce many volatile organic compounds that con-
   taminate the distillate and must later be removed by post-treatment.
   Two new nonoxidizing urine pre-treatment formulas have been tested
   which minimize the generation of volatile organics and thereby sig-
   nificantly reduce post-treatment requirements. Three post-treatment
   methods were identified from among the many candidates that look prom-
   ising for removing organic contaminants in recovered water to nonde-

tectable or barely detectable levels. Results of investigations are presented.

10. Rankin, J. Gary (JSC); Richter, R. F. G.; and Brennan, P. J.(OAO Corporation): Development of an Advanced Trapezoidal Axially Grooved (ATAG) Heat Pipe. Presented at the 4th Thermophysics and Heat Transfer Conference, June 2-4, 1986, Boston, Massachusetts.

The paper discusses the development of an advanced trapezoidal axially grooved (ATAG) heat pipe, which will satisfy space constructible radiator heat rejection requirements for large space power systems. The ATAG heat pipe development program includes a technology demonstration of Space Station heat load and temperature requirements through the design, fabrication, and testing of breadboard and preprototype units. The one-g transport capability will be at least 1.2 million watt-inches at an adverse elevation of 0.10 inches and an operating temperature of 20°C. The preprototype will also meet a proof pressure test of 1,200 psi, minimum. A parametric analysis has been conducted to determine trapezoidal groove geometries that can meet the 1.2 million watt-inches transport requirement and can be fabricated by available extrusion technology for a 1.54 inch outside diameter tube. This diameter was chosen to be compatible with the Vought contact heat exchanger. Analysis has shown that the transport requirements for 1.54 inch tubing can not be met using available direct extrusion techniques, but can be met by using the "draw-down" or swaging process on larger diameters.

11. Ray, Roderick J.; Newbold, David D.; Retzlaff, Sandra E. (Bend Research, Inc.); and Price, Donald F. (JSC): Membrane Based Techniques for very High Recovery of Space Station Waste Water. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California.

This paper describes the development of membrane-based subsystems designed to recover very high percentages of reusable water from various Space Station waste waters. The design, fabrication, and testing of a breadboard wash water purification subsystem will be described. Recovery of more than 99.5 percent of the water from raw wash water has been demonstrated by this subsystem. Data describing the efficient post-treatment of various streams are presented. The results of microbiological studies pertaining to these applications are also discussed.

12. Reysa, Richard P. (Boeing Aerospace Company): Regenerative Life Support System Hardware Testing. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California.

With the advent of the Space Station Program, regenerative environmental control and life support systems (ECLSS) are being considered to minimize logistics requirements, improve system performance, and reduce life-cycle costs. NASA sponsored regenerative ECLSS hardware development has been achieved through the Space Station Preprototype (SSP) and the Regenerative Life Support Evaluation (RLSE) programs, and ongoing advanced preprototype subsystem development and testing. The SSP program focused on regenerative life support techniques to satisfy projected goals of long-duration earth orbital missions.

Although the program was prematurely terminated by a funding redirection, portions of the regenerative atmospheric revitalization group (ARG) and water and waste management group (WWMG) were delivered to the NASA Johnson Space Center (JSC) for evaluation. The RLSE program continued to pursue this technology through fabrication of second generation ARG and WWMG subsystems that were tested at NASA JSC. Alternate technology advancement for major ARG and WWMG subsystem elements is being accomplished by individual advanced preprototype subsystem development. In concert with the technology programs, an advanced environmental control system (ECS) test laboratory designed to accommodate the unique requirements presented by regenerative ECLSS has been operational for 12 years. Technologies for six- and three-person oxygen generation, carbon dioxide removal, carbon dioxide reduction, phase change urine reclamation, hyperfiltration wash water reclamation, water quality monitor, organic content monitoring, and posttreatment have been characterized as subsystems and integrated ARG and WWMG systems.

13. Rogers, Leslie J. A. (Martin Marietta Denver Aerospace): The Next Step for the MMU--Capabilities and Enhancements. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California.

   The Manned Maneuvering Unit (MMU) was flown on three Shuttle flights during 1984 and demonstrated just some of its many capabilities. In addition to the satellite rendezvous, docking, and stabilization techniques already verified, the MMU has the capability to rescue disabled crew members, assist with satellite servicing and refueling, perform inspections and photography, and assist with on-orbit construction. Many of these capabilities have applications in both the Shuttle and Space Station eras. Various augmentations to the MMU are being considered and developed for these future applications. Enhancements discussed in this paper include a digital electronics assembly, navigation aid, and a propellant tank kit.

14. Sadunas, J. A.; Lehtinen, A. M; and Nguyen, H. T.: (Rockwell International); and Parish, Richard C. (JSC). Spacecraft Active Thermal Control Subsystem Design and Operation. Presented at the AIAA/ASME 4th Thermophysics and Heat Transfer Conference, June 2-4, 1986, Boston, Massachusetts.

   Future spacecraft missions will be characterized by high electrical power requiring active thermal control subsystems for acquisition, transport, and rejection of waste heat. These systems will be designed to operate with minimum maintenance for up to 10 years, with widely varying externally imposed environments as well as the spacecraft waste heat rejection loads. This paper presents the design considerations and idealized performance analysis of a typical thermal control subsystem with emphasis on the temperature control aspects during off-design operation. The selected thermal management subsystem is a cooling loop for a 47 Kw_e representative fuel cell, consisting of a fuel cell heat exchanger, thermal storage, pumps and radiator. Both pumped liquid transport and two-phase transport options are presented with similarities and differences for control requirements of these loops examined.

15. Sepahban, Sonbol (Lockheed Engineering and Management Services Company); Armeniades, Constantine (Rice University); and Moorhead, Louise (University of Texas Medical School): Investigation of Pharmacologic Treatments for Proliferative Vitreoretinopathy, Using the Vitreous Microtensiometer. Presented at the 4th Annual Meeting on Biomedical Engineering Research in Houston, February 14, 1986, Houston, Texas.

    Pharmacologic treatments for proliferative vitreoretinopathy (PVR) were evaluated by measuring in situ the tensile strengths of simulated membranes in rabbits, using the vitreous microtensiometer (VMT). Suction was exerted through the VMT capillary on membranes in freshly enucleated eyes. The stress at which a membrane disintegrated designated its tensile strength. Effects of treatments with Beta-amino-propionitrile (BAPN) and 5-fluorouracil (5-FU) on two types of PVR models were evaluated by the VMT. A combination BAPN-5FU therapy was found to significantly reduce strength of membranes induced by injection of retinal pigment epithelial (RPE) cells, at 99 percent confidence level, and to be effective in 50 percent of cases. These results demonstrate value of the VMT in assessing pharmacologic therapies for PVR. Drug-induced changes in strength of vitreous membranes are detected even in absence of clinical effects, thus leading to treatment optimization.

16. Stuart, Gary M; and Garcia, Kathy D. (Martin Marietta Denver Aerospace): Computer Simulation of On-Orbit Manned Maneuvering Unit Operations. Presented at the 1986 SAE Aerospace Technology Conference and Exposition, October 13-16, 1986, Long Beach, California. SAE Paper No. 861783.

    Simulation of spacecraft on-orbit operations is discussed in reference to Martin Marietta's Space Operations simulation laboratory's use of computer software models to drive a six-degree-of-freedom moving base carriage and two target gimbal systems. In particular, key simulation issues and related computer software models associated with providing real-time, man-in-the-loop simulations of the manned maneuvering unit (MMU) are addressed with special attention to how effectively these models and motion systems simulate the MMU's actual on-orbit operations.

17. Thoreson, Douglas W.; Rhodes, Gregg (Boeing Aerospace Company); and Parish, Richard C. (JSC): A Steerable Radiator for Spacecraft Application. Presented at the AIAA/ASME 4th Thermophysics and Heat Transfer Conference, July 14-16, 1986, Boston, Massachusetts.

18. Verostko, Charles E.; Garcia, Rafael; Pierson, Duane L. (JSC); Reysa, Richard P. (Boeing Aerospace Company); and Irbe, Robert (Northrop Services, Inc.): Results on Reuse of Reclaimed Shower Water. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California.

    A microgravity whole body shower (WBS) developed in Man Systems Division and the Crew and Thermal Systems Division's Waste Water Recovery System (WWRS) development hardware were used in a closed loop test where raw shower water was produced and processed for shower reuse. The WWRS included chemical pretreatment, phase change distillation and post-treatment for purification of shower water. Thermoelectric integrated hollow fiber membrane evaporation subsystem (TIMES) was the

phase change process employed and the post-treatment was accomplished with activated carbon and mixed ion exchange resin beds and a microbial check valve (MCV) iodine bactericide dispensing unit. The purpose of this test was to evaluate a NASA approved Shuttle soap for whole body showering comfort, evaluate the effects of the shower water on WBS and TIMES, and evaluate purification qualities of the recovered water in a closed loop operation. This paper describes the test hardware, the controls exercised for whole body showering, shower water collection and chemical pretreatment for microorganism control, TIMES operation and recovered water post-treatment. During the closed loop test, samples were taken to evaluate the water quality for both chemical and microbial impurities at selected locations through the water purification process. The water was recycled five times and findings demonstrate the feasibility and applicability of reusing reclaimed shower water in Space Station. Chemical pretreatment effectively controlled microorganism growth and the TIMES with post-treatment effectively reduced the organic impurities. The MCV provided adequate and positive disinfectant.

19. Webbon, Bruce W. (SRI International): An Evaluation of Automatic Control System Architecture for EVA Portable Life Support Systems. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California.

Automatic control of various functions of an extravehicular activity (EVA) portable life support system (PLSS) would provide improvements in crew productivity and comfort as well as the PLSS operating efficiency. A key element in the control system is the selection of the optimum controller input parameters. Careful choice of inputs will allow the controller to calculate and provide valuable system status and safety information as well as to perform the basic control functions. This paper reports on the results of a study in which the full range of possibly relevant inputs was considered. Arguments are presented leading to the selection of the recommended control system architecture.

20. Whitsett, Charles E: Role of the Manned Maneuvering Unit for the Space Station. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California. Paper No. 861012.

The manned maneuvering unit (MMU) has been flown on nine sorties and has accumulated 10 hr and 22 min of flying time during three Space Shuttle missions. These Space Shuttle flights have demonstrated a capability for free space traverses up to 98 m (320 ft), cargo transfer, and tracking, docking, stabilizing, and orienting large satellites. These and additional MMU capabilities will benefit the Space Station and its onboard payloads. First and foremost is the capability to rescue an EVA crewmwmber who might inadvertently separate from the Space Station. There will also be tasks at worksites inaccessible by other Space Station equipment and tasks where EVA time is critical. Many Space Station and payload assembly and inspection tasks will need MMU support. Significant Space Station mission flexibility is added by the MMU for backup and contingency roles. These Space Station roles will require a major upgrade to the Space Shuttle MMU design.

21. Winkler, H. Eugene; Goodman, Jerry R. (JSC); Murray, Robert W. (General Electric Company); and McIntosh, Mathew E. (Rockwell International): Shuttle Waste Management Sytem Design Improvements and Flight Evaluation: Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California.

The Shuttle waste management system has undergone a variety of design changes to improve performance and man-machine interface. These design improvements have resulted in more reliable operation and hygienic usage. The design enhancements include individual urinals, increased urine collection air flows, increased solids storage capacity, easier access to personal hygiene items, and additional wet trash stowage. This paper describes the development and flight evaluation of these improvements. The Shuttle Orbiter has proved to be an invaluable test bed for development and inflight evaluation of life support and habitability concepts which involve transport or separation of solids, liquids, and gases in a zero-gravity environment.

Advanced Programs Office

1. Ashley, W. H., Jr. (IBM): Writing Reusable Software for Large Systems: A Cleanroom Derivative. Published in <u>Technical Proceedings of the Programming Development Process Symposium</u>, April, 1986, Poughkeepsie, New York.

   This paper describes reusable software applications. Application examples include error prevention (rather than error detection), stepwise refinement, data encapsulation, data-directed design, data and functional abstraction, and PL/I. Examples from STAR'S development are given of structured specifications, functional abstraction, data abstraction, data-directed design, encapsulation, and reusable software. The structured specification for STAR uses a state machine informal specification of the STAR system. A model is included for writing reusable software as derived from the STAR software design and code. A discussion is given on the organization and implementation of the STAR reusable software.

2. Blackwell, Harvel E. (Texas Southern University); Scott, Carl D.; Hoffman, Jeffery A. (JSC); Mende, Stephen B.; and Swenson, Gary R. (Lockheed Palo Alto Research Laboratory): Spectral Measurements of the Space Shuttle Leeside Shock Layer and Wake. Presented at the AIAA/ASME 4th Joint Thermophysics and Heat Transfer Conference, June 2-4, 1986, Boston, Massachusetts. AIAA Paper No. 86-1262.

   Leeside shock layer and wake spectral radiation measured during the high altitude portion of the reentry of Space Shuttle Orbiter STS 51-D are presented and are compared with similar measurements obtained in an arc jet tunnel. The spectra, measured with a low-reslution spectral camera, are compared in order to identify the radiating species in a wavelength range from 4000 to 8000 angstroms. High-resolution measurements of the arc jet spectra were available to aid in identifying species contributing to the radiation measured with the low-resolution instrument. In addition, a nonequilibrium air radiation calculation technique is used to aid in the identification and to obtain some qualitative information about the temperature of the radiating species. Emissions identified are: N_2 first positive and N_2 second positive systems, the N_2+ first negative system, and the sodium-D lines. No atomic air species or CN are observed. The spectra and procedure will be of use in comparison of flight flowfield properties with computational predictions and for guidance in developing future flight experiments.

3. Craig, Roy R. (University of Texas at Austin): Application of Compound Mode Synthesis in Structural Dynamics. Presented at the International Conference on Vibration Problems in Engineering, June 17-20, 1986, Xian, China.

   This paper summarizes the principal analytical techniques used for component mode synthesis of undamped structures. A new form of component mode, called an applied force attachment mode, is described. Recent contributions to the literature on synthesis of damped structures are noted, and the paper concludes with a brief discussion of recent combined analytical/experimental studies.

4. Fairchild, Kyle; and Roberts, Barney: Modeling and Simulation of a Lunar Base and Associated Space Transportation System. Presented at Symposium '86, September 22-24, 1986, Atlantic City, New Jersey. (To be published in Proceedings.)

   This paper introduces a computer model, composed of sets of subsystem modules, organized by function, that allows decision makers to quickly assess the impacts of various options for a lunar base and the associated space transportation systems. The model, when fully mature, will assist in the generation and documentation of detailed scenarios including development and operational costs, networks, processes, products, and capabilities. Upon release, this model will go under configuration control to allow systematic and controlled updates. New revisions will be made to include new subsystem modules and more accurately model the transforms that define the relationships among the various subsystems, as these relationships are better understood. Premature decisions based on insufficient information can be minimized. Implications of design tradeoffs are more readily apparent. Common sets of definitions are established and system boundaries firmly defined. The model is also self-documenting. The evolution of long-term, large scale projects is preserved in detail. Past decisions and their justifications can be revisited and modified to account for the changing technological and political environment. In the near term, this model can help identify the common subsystems that will be needed in any lunar base scenario, no matter how aggressive or austere.

5. Goza, S. Michael: Photographic Analysis Using Solid Models. Presented at the Structural Dynamics Research Corporation Users Group Conference Procedures, October 20, 1986, Milford, Ohio. Published in 1986 I-DEAS User's Conference Proceedings, pp. 69-77.

   Engineers within the JSC Advanced Programs Office (APO) were put in charge of visual analysis of photographic data extracted from the STS 51-L tracking cameras. Part of the visual analysis involved pinpointing coordinates of specific areas on these photographs. The solid modeller, GEOMOD, inside the SDRC I-DEAS package, proved invaluable to the study. This paper discusses the problem areas and their resolution in the performance of the study. These areas include the creation of computer models representing real structures using GEOMOD, the positioning of the structure to make it match photographic orientations, and the use of GEOMOD abilities to extract coordinates and to place markers on the solid model to match photographic areas of interest. As part of this discussion, GEOMOD's advantages and disadvantages will be revealed, as well as the mathematics involved in determining eye position for correct photographic matching. Also, the area of perspective viewing with respect to telephoto lenses will be highlighted.

6. Li, Chien-peng: Computation of Three-Dimensional Flow about Aerobrake Configurations. Presented at the 24th AIAA Aerospace Sciences Meeting, January 6-9, 1986, Reno, Nevada. AIAA Paper No. 86-0566.

   A simple and efficient method proposed earlier to compute the full viscous flow over a hypersonic aerobrake body at angles of attack has been improved, and its results are evaluated against available data. The method numerically solves for the shock layer ahead of the body

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and the trailing wake from the Navier-Stokes equations formulated in conformal polar and azimuthal-angle coordinates. The computational domain is confined by the body wall, outflow surface and the bow shock, which is adjusted along the radial direction iteratively. The algebraic grid and the well-developed alternating direction implicit factorization technique are credited with the rapid convergence rate and reasonably accurate results obtained with 400 time-marching iterations on a 28 x 36 x 7 grid. Agreement is satisfactory between the predicted shock shapes and the schlieren photographs, and in the wall pressure distributions for two ellipsoid-cones of 1:3.07 and 1:10 and for a 70° cone-cylinder. Details of the base flow on the pitch plane and the shear-layer impingement on the cylindrical afterbody are presented for an ellipsoid-cylinder aerobrake body.

7. Li, Chien-peng: Efficient Computation of Chemically Nonequilibrium Flow Around Blunt Bodies. Presented at the 10th International Conference on the Numerical Methods for Fluid Dynamics, June 23-27, 1986, Peking, China. Published in <u>Lecture Notes in Physics</u>, Vol. 264, pp. 406-415, 1986.

The backward Euler scheme was used to solve a large system of inviscid flow and chemical rate equations in three spatial coordinates. The flow equations were integrated simultaneously in time by a conventional ADI factorization technique, then the species equations were solved by either simultaneous or successive technique. The methods were evaluated in their efficiency and robustness for a hypersonic flow problem involving an aerobrake configuration. It was found that both implicit methods can effectively reduce the stiffness associated with the chemical production term and that the successive solution for the species was as stable as the simultaneous solution. The latter method is more economical because the computation time varies linearly with the number of species.

8. Li, Chien-peng: Euler Solutions Using an Implicit Multigrid Technique. NASA TM-58276, November, 1986, 18 p.

A coarse-grid correction algorithm has been imlemented into an implicit upwind Euler solver and tested for transonic airfoil problems. The Euler solver uses split-flux formulation and penta-diagonal scalar equations, respectively, for the explicit and implicit operators. The multigrid sequence starts at the fine grid level, then steps down to each coarse grid level to smooth error components using implicit operators. Estimate of residuals can be obtained by two approaches, which differ in the level where the residuals are collected. Both approaches will lead to a work reduction factor of 12 for a Mach 0.75 flow at 2 degrees incidence on a 65x26 grid. The work reduction factor is found to increase proportional to the number of grid levels.

9. Li, Chien-peng: Implicit Methods for Computing Chemically Reacting Flow. NASA TM-58274, August, 1986, 14 p.

The backward Euler scheme was used to solve a large system of inviscid flow and chemical rate equations in three spatial coordinates. The flow equations were integrated simultaneously in time by a conventional ADI factorization technique, then the species equations were solved by either simultaneous or successive technique. The methods were evaluated in their efficiency and robustness for a hypersonic

flow problem involving an aerobrake configuration. It was found that both implicit methods can effectively reduce the stiffness associated with the chemical production term and that the successive solution for the species was as stable as the simultaneous solution. The latter method is more economical because the computation time varies linearly with the number of species.

10. Ried, Robert C., Jr.: The Challenge of Aerobraking. Presented at the American Astronautical Society, October 26-29, 1986, Boulder, Colorado. AAS Paper No. 86-349.

    The technology and spacecraft design challenges of aerobraking are discussed as related to the bold agenda formulated by the National Commission on Space to carry America's civilian space enterprise into the 21st century. The efficiency and systematic progression achieved through the synergism of a low Earth orbit spaceport, Earth to spaceport transportation, and a space based reuseable aerobraking orbital transfer vehicle are discussed. The low Reynolds number hypersonic aerodynamics and aerothermodynamics phenomena are presented along with the requirements for understanding the nonequilibrium chemistry and thermodynamics through ground experiment, computational chemistry, and computational fluid dynamics. The rationale for a proposed aeroassit flight experiment to provide certification of our understanding and the associated computational capabilities is discussed as it pertains to obtaining efficient spacecraft design and capability development.

11. Ried, Robert C., Jr.: A Flight Test Challenge: Aeroassist for Reusable, Space-Based Transportation. Keynote speech at the 9th Aerospace Testing Seminar, October 1985, Los Angeles, California. Published in the Journal of Environmental Sciences, Vol. 29, No. 5, pp. 26-31, September/October, 1986.

    The challenge of developing reusable, space-based transportation systems which can take advantage of aerobraking to achieve greater performance and overall efficiency is addressed. Aerobraking environmental factors associated with achieving higher energy reusable systems are delineated along with the need for a coupled utilization of ground test capabilities and computational fluid dynamics (CFD). The validation of the required level of understanding and certification of this approach for the design of an aerobraking orbital transfer vehicle (AOTV) requires a flight test. The certification of CFD capability to provide the aerodynamic performance and aerothermodynamic environment for an AOTV would be a major technological milestone in achieving a more productive approach to the design and development of flight systems.

12. Roberts, Barney B.: Martian Settlement. Presented at the Goddard Memorial Symposium, March 19-21, 1986, Greenbelt, Maryland.

13. Roberts, Barney B.: Mission Analysis for Future Lunar Bases. Presented at the American Astronautical Society Annual Meeting, October 26-29, 1986, Boulder, Colorado.

The development and evolution of an aggressive lunar base conceived on a principle of continuous growth towards an objective of self-sufficiency is presented. The surface mission objectives and support systems are discussed in some detail in order to understand the requirements of alternative transportation system technologies and system elements. Trade study results qualify the benefits and costs of the various transportation system assumptions. Systems include conventional chemical propulsion concepts, advanced chemical propulsion, electric propulsion (with varying energy sources), momentum exchange devices (tethers), and electromagnetic launchers and reaction engines. Several concepts of lunar propellant supply systems are also be included in the trade study results.

14. Roberts, Barney B.: Non-Terrestrial Sources of Helium-3. Presented at the 28th Annual Meeting of the American Physical Society Division of Plasma Physics, November 4-6, 1986, Baltimore, Maryland.

Apollo lunar exploration results demonstrate the existence of helium-3 of solar origin impacted into the lunar soil by the solar wind. The concentration of helium in lunar soils ranges from less than one ppm to about 35 ppm, with an average soil concentration in the lunar maria containing about 15 ppm. The concentration increases with decreasing grain size; in the size fraction smaller than 20 microns in some Apollo 17 soils, the concentration is approximately 50 ppm. The mineral ilmenite has also preferentially retained helium, with concentrations of up to 25 ppm reported in separated fractions. Some soil breccias have helium concentrations higher than that in surface soils. The ratio of helium 4 to helium 3 is 2200:3000 in various soil and soil fraction samples. Techniques for extraction have been proposed that utilize either heat or mechanical means to release the helium. Recent lunar base studies at the Johnson Space Center have defined the systems for various lunar surface development scenarios and the associated transportation systems that are required to support the base. One or two round trips of the proposed transportation system elements have the capacity to deliver, to the surface of the Earth, enough helium-3 to supply the electrical energy needs of the United States for one year. Using the cost data generated for this lunar base study, it is possible to approximate the marginal cost for the production and delivery of the helium-3.

15. Roberts, Barney B.: A Transportation System for Routine Visits to Mars. Presented at the Mars Conference, July 21-23, 1986, Washington, D.C.

16. Roberts, Barney B.: A Twenty-first Century Lunar Base. Presented at the Symposium '86, September 22-24, 1986, Atlantic City, New Jersey.

The development and evolution of an agressive lunar base conceived on a principle of continuous growth towards an objective of self-sufficiency is presented. The surface mission objectives and support systems are discussed in some detail in order to understand the requirements of alternative transportation system technologies and system elements. Trade study results qualify the benefits and costs of the various transportation system assumptions. Systems include con-

ventional chemical propulsion concepts, advanced chemical propulsion, electric propulsion (with varying energy sources), momentum exchange devices (tethers), and electromagnetic launchers and reaction engines. Several concepts of lunar propellant supply systems are also be included in the trade study results.

Tracking and Communications Division

1. Cooke, W. P.; Dunn, A. G; Johnson, R. C; Montgomery, J. P.(Georgia Institute of Technology); and Eggers, Donald S. (JSC): Antenna Design Concepts for the U. S. Space Station. Presented at IEEE Antennas and Propagation Symposium, June 8-13, 1986, Philadelphia, Pennsylvania. Published in AP-S Symposium Digest, Vol. II, p. 731. Georgia Tech Research Institute Project No. A-4183.

   An analysis has been performed to assess the suitability of various antenna design approaches for the initial operational configuration (IOC) of the U.S. Space Station. Coverage zones in the vicinity of the Space Station have been defined for specific communication purposes. Individual, mechanically steered antennas have been compared with electronically scanned and multiple-beam antennas for each zone.

2. Davidson, Shayla E.: Advanced Synthetic Aperture Radar Antenna. Presented at the 11th Annual AIAA Technical Symposium, May 9, 1986, Houston, Texas.

   The multifunction synthetic aperture radar antenna technology (MSART) program was tasked with the definition and development of advanced antenna technology in support of future spaceborne synthetic aperture radar (SAR) systems such as the Shuttle imaging radar (SIR) program. Spaceborne SAR systems were required to perform multiple missions and support multiple functions. In the case of Shuttle missions, the antennas were required to be restowed for return to the earth. The systems were also required to be cost effective and reliable. Long lifetimes are anticipated for Space Station and satellite missions, making reliability a more critical requirement in these cases. This paper presents the history and the results of the MSART program, including the hardware prototypes developed. The three basic antenna technologies, slotted waveguide, open ended waveguide, and microstrip with distributed amplifiers, are compared.

3. Davidson, Shayle E.: Antennas for Spacecraft Synthetic Aperture Radars. Presented at the 1986 IEEE Radar Conference, March 12, 1986, Los Angeles, California.

   Future synthetic aperture radar (SAR) missions will require lightweight multifrequency, multipolarization spacecraft antennas. NASA has conducted an investigation of possible antenna technologies, and has identified two promising technologies: interleaved open ended waveguide antennas constructed from metallized graphite epoxy and distributed microstrip antennas. The investigation and candidate technologies are described in this paper.

4. Davidson, Shayla E.: Phased Array Antennas for Space Applications. Presented at the 11th Annual AIAA Technical Symposium, May 9, 1986, Houston, Texas.

   Future space antennas will require electronic beam sterering to satisfy mission requirements. Phased array antennas are necessary to perform this function. Distributed amplifiers can also be added to enhance reliability and improve system link margins. JSC is developing two phased array antenna breadoards in house, one as a possible upgrade to the Shuttle's S-Band system, and one as a candidate antenna

for the Space Station multiple access system. Both antennas have distribued amplifiers and phase shifters at the element level, but the design approaches for the two antennas vary, depending upon mission requirements and interfaces with other parts of the vehicle they support. The design approaches and hardware developments are presented in this paper.

5. Davidson, Shayla E.: Phased Array Antenna for Space Shuttle Orbiter. Presented at the 1986 Symposium on Antenna Applications, September 17-19, 1986, Monticello, Illinois.

   NASA is developing a distributed phased array antenna at the Johnson Space Center as a possible upgrade for the Space Shuttle Orbiter S-band phase modulation communications system. The antenna consists of an eight element transmit section, eight element receive section, and a single L-band receive element. Each transmit chain consists of a phase shifter, a high power amplifier, and a right handed circularly polarized (RHCP) microstrip element. Each S-band receive chain consists of a RHCP microstrip element, a low noise amplifier, and a phase shifter. There is also an eight-way power divider for the transmit section and an eight-way power combiner for the S-band receive section. The transmit section, S-band receive section, and L-band receive element are mated to a single RF connector via a triplexer. The antenna design was constrained by the existing Orbiter system and space environment. The solution to the interface design problems led to an antenna system which provides improved link margins and yet supports previous operational configurations.

6. Erwin, Harry O.: Laser Docking System Radar Flight Experiment. Presented at the SPIE 1986 International Symposium on Optical and Optoelectronic Applied Sciences and Engineering, June 2-6, 1986, Quebec City, Canada.

   The tracking Techniques Branch of the Johnson Space Center has had a 5-year effort to develop advanced rendezvous, stationkeeping, and docking sensors. This effort was in response to an identified NASA need for a development program to address the long term tracking needs of Shuttle, Space Station, manned maneuvering units, orbital transfer vehicles, orbital maneuvering vehicles, tethered satellites, satellite servicing, and other free flying experiments and payloads. One result of this effort has been the design, development, and breadboarding of a laboratory model of a laser docking system radar, which uses a solid-state laser to measure target position and attitude for a large variety of vehicles and payloads. The next step in the verification of the laser docking system radar is its use in flight experiments aboard the orbiter. Experiments are planned which will allow flight experience to be gained for the laser docking system radar with minimum impact to the orbiter. The radar would be mounted in the payload bay of the orbiter in the location which would allow a view of the -Z docking axis. A grid computer would be used inside the cabin to provide control to and display data from the radar. The connection between the radar and the grid will be a fiber optics link that looks through a very small part of the aft orbiter window. This method will eliminate the need for complex orbiter interfaces or modifications. The laser docking system radar will be manifested as a piggyback experiment on normal retrieval missions. The radar will operate in a

data taking and displaying mode while the crew carries out manual sta-
tionkeeping and docking maneuvers. The data from the flight experi-
ments will then be used to design an operational sensor that is small,
lightweight, and capable of meeting the long term tracking needs of
NASA and industry in rendezvous stationkeeping, docking, berthing, and
robotic control.

7. Grady, Jane L.: An Optical Communication Link on the Shuttle. Presen-
   ted at the IEEE/AIAA Digital Avionics Systems Conference, October 13-
   16, 1986, Fort Worth, Texas. Published in <u>Proceedings</u>, pp. 419-424.
   When the cables between the crew cabin and the payload bay on the
   Shuttle were chosen, all the special data needs for payloads were not
   known. As a consequence, for some payloads, special accommodations
   have to be made to transfer needed data between the cabin and the pay-
   load bay (e.g., a new penetration is sometimes needed in the pressure
   vessel so that cable needed to accommodate higher data rates for a
   particular payload can be installed). This special action requires
   much time and money. A conventional fiber-optics feed-through is dif-
   ficult and costly, so a special way of transmitting data optically
   through a spot in the corner of the cabin window is being developed.
   This system would not only solve data bandwidth problems, but would
   also provide a communication link which would not depend on the ex-
   isting Orbiter link. The following is a look at system design and
   engineering considerations in the development of the Optical Com-
   munications through the Shuttle Window (OCTW) system.

8. Halsema, P. B. (Harris Corporation): Multiple Beam Phased Array for
   Space Station Control Zone Communications. Presented at the Global
   Telecommunications Conference 1986, December 1-4, 1986,
   Houston, Texas.
   The Space Station Control Zone is a disc shaped region 40 nautical
   miles in diameter and 10 nautical miles thick around the Station. It
   is estimated that 6 simultaneous multiple access (MA) channels will be
   required to satisfy the projected communications needs within this
   zone. These channels will be used to communicate with MA users lo-
   cated anywhere within the control zone. This paper details the trade-
   offs and design implementation of a multiple beam integrated phased
   array to provide antenna coverage of the control zone. The array is a
   compact, modular assembly using gallium arsenide circuits, microstrip
   elements, and advanced packaging techniques. This results in a small,
   reliable antenna system capable of meeting the projected Space Station
   requirements and flexible enough to grow and evolve as the Space
   Station communications needs develop.

9. Juday, Richard D.: Fourier Optics Vision in a Control Systems Environ-
   ment. Presented at the International Conference on Applications of
   Lasers and Electro-Optics, November 10-13, 1986, Arlington, Virginia.
   Optical information processing offers a method of synthetic vision
   that is characterized by speed, light weight, reliability, flexi-
   bility, and simplicity, when compared with the digital computation
   approach. In automating many operations in the Space Station era,
   NASA will have significant application for such a vision system, and
   there are many other applications that make similar demands. We ex-
   amine the ramifications of using an optical information processing ap-

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proach in conjunction with a control system. Some aspects of the interaction are the following: (1) the sequence of filters used in a programmable vision system, separately to estimate distance and relative attitudes, (2) the information required to run the vector Kalman filter, and implications for vision system design, (3) covariance, uncertainty, and time autocorrelation (independence) of estimates, and how they relate overall control sytem performance requirements to vision system requirements, (4) speed: frequency of updates of estimates and lag time between a measurement and delivery of the resulting estimate, (5) the two-way flow of information and the division of processing between the sensor system and the control system, when the vision system has a limited port into the control system and must process information with some ignorance of the total environment, (6) predicted motion as used to select attitude-estimating filters in the vision system.

10. Juday, Richard D.: Optical Correlator Use at Johnson Space Center. Presented at the SPIE Technical Symposium Southeast on Optics and Optoelectronic Systems, March 31 - April 4, 1986, Orlando, Florida.

For automation and robotics applications in the Space Station era, NASA's Johnson Space Center is pursuing several means of synthetic vision. Autonomous servicing of satellites, automated docking of large space structures, and electromagnetically passive station-keeping are a few of the applications of synthetic vision, and the optical correlator is one of our approaches. The deformable mirror device of Texas Instruments will form the basis of the first correlator in this project. The in-house activities will include an adaptive impulse deconvolution method of characterizing it to allow its operation as a phase-only filter. The in-house portion of the project will include a programmable remapper to accomplish some standard spatial remappings of the input image for rotation and scale invariance. Primitive edge operators, anti-aliasing as scale changes, and complete flexibility in remapping the input image can be accomplished. Contracted efforts in optical processing pattern recognition are described.

11. Krishen, Kumar: Advanced Tracking, Communications, Automation/Robotics Vision Concepts/Systems/Studies. Presented at the Graduate Seminar Series-University of Houston-University Park, November 10, 1986, Houston, Texas.

Recent advancements in the areas of tracking, communications, automation/robotics vision sensors as applicable to space programs will be discussed. Optical and laser-based communications and tracking system implementations will be presented. Technology advancements in these systems will be highlighted. Communications systems for broadband, high data rates, and efficient operation will be discussed. The state-of-the-art at 20/30 GHz and millimeter wavebands will be summarized. Other topics to be discussed will include: optical data processing, TV-based vision systems, laser vision sensors, and microwave imaging for vision applications. The fusion of these sensors for remote control, rendezvous, stationkeeping, tracking, and satellite repair will also be presented.

12. Loh, Y.C.; Shelton, K.W.; and Tu, K. (Lockheed Engineering and Management Services Company): Antenna Systems and RF Coverage for the Space Station. Presented at the IEEE Global Communication Conference, December 1, 1986, Houston, Texas. Published in <u>Proceedings</u>.

This paper presents some of the results on the radio frequency (RF) coverage analysis of the Space Station (SS) to Tracking and Data Relay Satellite Systems (TDRSS) links and the multiple-access (MA) links. The antenna systems for both types of communication links were identified by considering typical operational scenarios, different types of services needed, and the architecture of the communication system. The paper describes the obscuration analysis tools for the placement of the antennas and an optimization procedure used to design the MA near range antenna system.

13. Loshin, David S. (University of Houston-University Park) and Juday, Richard D. (JSC): Programmed Remappings for Investigating Optimal Images for Low Vision Patients. Presented at the 1986 American Academy of Optometry Meeting, December 6-9, 1986, Toronto, Ontario.

Many low vision patients have only limited areas of the retina that are capable of transmitting an image to the visual cortex. Hardware is being developed (for possible future implementation as a practical low vision device) that will real-time spatially remap the entire visual space into the still active areas of the retina. The hardware will be used to investigate candidate remappings for maculopathies, retinitis pigmentosa, and perhaps glaucoma. The Jacobian spatial discriminant theory behind the candidate remappings was presented, and static images that have undergone these remappings were shown.

14. Mackiw, G. E. (RCA): Multiple Access Ku-Band Communications Subsystem for the Space Station. Presented at the 7th Digital Avionics Systems Conference, October 13-16, 1986, Fort Worth, Texas. Published in <u>Proceedings</u>.

Results are presented of advanced work being performed at RCA on system design for the Space Station multiple access subsystem which includes equipment aboard the Space Station itself, and aboard the spaceborne group of user vehicles. In addition to the system development efforts, early hardware design work is being performed. A Ku-band transceiver representing the extravehicular activity (EVA) or other user equipment configuration has been breadboarded and system testing performed. Additional hardware which will be assembled to form a Space Station multiple access (MA) communications subsystem test bed where the subsystem itself, as well as its hardware components, will be tested and evaluated. The design described was developed by RCA for NASA for evaluation purposes only and does not necessarily represent the design to be implemented on the Space Station. In particular, the radio frequency band final selection has not yet occurred.

15. Olson, Nanci A. (JSC): Space Station Multiple Access Communications
    Systems. Presented at the IEEE Global Telecommunications Conference,
    December 3, 1986, Houston, Texas. Published in <u>IEEE Globecom Pro-
    ceedings</u>, 1986.
        A breadboard of the baseline Space Station multiple access commu-
    nications system is being developed by RCA under contract to JSC. The
    preliminary design supports up to seven high data rate users and up to
    twelve low data rate users. Additional users are accommodated through
    a demand-assignment orderwire channel. A maximum of 22 Mbps can be
    transmitted for each high rate channel, and 500 kbps can be transmit-
    ted by each low rate channel. The system transmits in a band from
    13.4 to 13.7 GHz and receives in a band from 14.6 to 14.89 GHz. It ·
    has a distributed architecture with modulators/demodulators and IF
    components located centrally, and signals distributed by an IF bus.
    Fiber optics and coaxial cables are being studied for the IF bus me-
    dia. RF components are located at the antenna sites. The distributed
    system approach minimizes the duplication of Space Station equipment
    and signal losses in long cable paths.

16. Raffoul, George W. (Lockheed Engineering and Management Services Com-
    pany): A Shuttle S-Band Distributed Array Antenna. Presented at the
    Lockheed Electromagnetics/Low Observable Symposium, September 30 –
    October 3, 1986, Burbank, California. Published in <u>Proceedings</u>.
        A proposed enhancement to the existing Space Shuttle S-band antenna
    system used to communicate to ground directly or via the Tracking and
    Data Relay Satellite (TDRS) is described. Improvement on the order of
    11 to 14 db is expected in the communication link circuit margins.
    The new antenna system uses a distributed phased array design in which
    power amplification is distributed over an array of circularly polar-
    ized patch elements and located next to these elements, eliminating
    excessive cable losses and forming the key to the improved performance
    in the new design. The radiating beam generated by the array is elec-
    tronically steered toward its target where pointing information is ob-
    tained from the Shuttle general purpose computer (GPC) via multiplex-
    er/demultiplexer (MDM) interface.

17. Ratliff, James E.; Space Station Communications System Design and
    Analysis. Presented at the 37th IAF Congress, October 4-11, 1986,
    Innsbruck, Austria.
        The Johnson Space Center is responsible for the definition, design,
    and development of the communications system for the Space Station
    Program. This task is enormous in light of the inherent complexity of
    spaceborne systems, the number of simultaneous communications links
    required to support Space Station operations, and the magnitude of de-
    sign variables. The purpose of this paper is to discuss the role of
    the communications system in the overall Space Station Program in re-
    gard to the impacts placed on its design, and to present the methods
    developed to perform the design and analysis of the Space Station
    communications system.

18. Ratliff, James E. (JSC); Tsang, Chit-Sang; and Chie, Chak-Ming (LinCom

Corporation): FDMA System Design and Analysis For Space Station.
Presented at Globecom '86, December 2-5, 1986, Houston, Texas.

Space Station FDMA communications system requirements, design and analysis are addressed. The analysis is primarily based on numerical results generated by a computer simulation system called SCSS. The time-line communications performance during real time mission operation is also discussed. The purpose of this paper is threefold: introduction to Space Station multiple access communications system requirements, demonstration of system analysis by a computer tool, and design of a FDMA communications system for the Space Station.

19. Schmidt, Oron L.: Expert Systems for the Control and Monitoring of the Space Station C&T System. Presented at the Instrument Society of America Clear Lake/Galveston Meeting, June 5-6, 1986, Houston, Texas. Published in ROBEX '86 Proceedings.

The Space Station communications and tracking (C&T) system's control and monitoring subsystem (CMS) will employ a network of computers to perform complex management and status monitoring functions. Workstations will be provided for crewmen to select C&T services and monitor status. Ex-pert systems will be developed for the CMS to assist the crew in managing the complex C&T system with minimal ground support. Provisions will be made to incorporate "intelligence" in the form of rules into the CMS central computer software to automatically deal with the routine C&T system management and status monitoring functions. As more is learned about how to operate the C&T system it will be incorporated into the CMS expert systems until most of the management decisions will be made onboard. Several implementation approaches are being considered such as Lisp coprocessors, multi-tasking CPU's with embedded expert system software and stand-alone expert system processors. These hardware approaches and several software development approaches will be evaluated in a CMS prototype development system at JSC.

20. Shaw, Roland; and Kovitz, Jeff (Lockheed Engineering and Management Services Company): A Distributed Array Antenna System. Presented at the IEEE Microwave Theory and Techniques Symposium, June 2-5, 1986, Baltimore, Maryland. Published in Proceedings, June, 1986.

The Space Station communication system will use microwave frequency radio links to carry digitized information from sender to receiver. The ability of the antenna system to meet stringent requirements on coverage zones, multiple users, and reliability will play an important part in the overall multiple access communication system. This paper describes the configuration of a multibeam conformal phased array antenna and the individual microwave integrated components incorporated into this antenna system.

21. Shaw, Roland; and Kovitz, Jeff (Lockheed Engineering and Management Services Company): A Distributed Array Antenna System for the Space Station Multiple Access Network. Presented at the Lockheed Electromagnetics Symposium, September 29 thru October 3, 1986, Burbank, California. Published in Proceedings, November, 1986.

One of the antenna systems being proposed for the Space Station multiple access communication system is based on the use of a multibeam conformal phased array. The system is a 5 channel, full duplexed, Ku-

Band frequency division multiple access scheme which will allow communications from 1 kilometer to 185 kilometers from the Space Station structure. Implementation involves the design of microwave components such as low noise amplifiers, high power amplifiers, phase shifters, and the integration of these components into the antenna structure. Significant interest has been given to monolithic circuits integrated into an array of microstrip patch antennas. Space Station use of a conformal array is desired because of the spherical nature of the gain/coverage requirement.

22. Tang, Sophia (JSC); Cooke, W. P.; Dunn, A. G.; Jameson, C. R.; Joy, E. B.; and Montgomery, J. P. (Georgia Institute of Technology); and Eggers, Donald S. (JSC): Development of A Large Near Field Measurement System for Testing Spaceborne Antennas. Presented at the 1986 Antenna Measurement Techniques Association Symposium, September 23-25, 1986, Ottawa, Canada. Georgia Tech Research Institute Project No. A-4291.

A horizontal, planar-scan, near field measurement facility for testing spaceborne antennas has been developed for Johnson Space Center. The probe scanner will be located near the ceiling of an existing anechoic chamber. The available scan area approaches 40' x 40', one of the largest installations developed to date. The mechanical deflections of the steel translation beam which supports the probe carriage are to be less than +0.005 inches. Rigid environmental control will be necessary to preserve the mechanical accuracy of the scanner, as well as the precise alignments of the lasers and optical components used for position measurement and control. Four linear measurements will be used to locate the position of the translation beam and probe carriage. A combination of ten additional angular and straightness measurements will be obtained for characterizing the planarity of the probe. Position errors will be compensated by a software algorithm. Probe travel rates up to 30 in./sec. will be possible in the initial installation. Also, a configuration of high data rate receivers is planned. The capability of processing a 5K x 5K data set will be provided.

Simulation and Avionics Integration Division

1. Baker, T. C.; Lennington, R. K.; Herold, R. W.; and Bennett, W. P.:
   (Lockheed Engineering and Management Services Company): An Expert
   System for Space Station Activity Scheduling. Presented at the Second
   Annual Workshop on Robotics and Expert Systems, June 5-6, 1986,
   Houston, Texas.
      This paper discusses all aspects of the crew control mockup plan-
   ning expert (CCMPE) development project. Special emphasis is given to
   the planning and scheduling architecture employed by the CCMPE. An
   example illustrating the problems associated with planning in a dynam-
   ic environment is included. Other topics discussed include: hardware
   and software interface issues; project management issues; and planned
   follow-on activities.

2. Healey, Kathleen Jurica, editor: Artificial Intelligence Research and
   Applications at the NASA Johnson Space Center. Part I published in AI
   Magazine, Vol. 7, No. 2, pp. 101-115, Summer, 1986; Part II published
   in Conference 1986, AI Magazine, Vol. 7, No. 3, pp. 146-152.
      Research and applications work in AI is being conducted by several
   groups at JSC that interact with each other on an informal basis. In
   the Research and Engineering Directorate, these groups include (1) the
   Artificial Intelligence and Information Sciences Office, (2) the Simu-
   lation and Avionics Integration Division, (3) the Avioncs Systems Di-
   vision (ASD), and (4) the Tracking and Communications Division. In
   the Space Operations Directorate, these groups include (1) the Mission
   Planning and Analysis Division--Technology Development and Applica-
   tions Branch, (2) the Spacecraft Software Division, and (3) the Sys-
   tems Division--Systems Support Section. The first part of the article
   describes the AI work in the Research and Engineering Directorate.
   The second part of the article, to be published in the Conference edi-
   tion of the AI Magazine, describes the AI work in the Space Operations
   Directorate.

3. Kohn, Wolf; Dunn, C. (Lockheed Engineering and Management Services Com-
   pany); and Healey, Kathleen J. (JSC): Implementation of Real-Time Ex-
   pert Systems in Prolog. Presented at ROBEXS '86, June 5-6, 1986,
   Houston, Texas.
      This paper presents an approach to implementing in Prolog expert
   systems which operate under real-time constraints. Real-time con-
   straints are defined as requirements for the expert system to respond
   to a universe state change in a prespecified time interval. In aero-
   space domains this time interval is typically in the 80ms to 1 second
   range.

4. Kohn, Wolf (Lockheed Engineering and Management Services Company); and
   Healey, Kathleen J. (JSC): Trajectory Planner for an Autonomous Free-
   Flying Robot. Presented at the 1986 IEEE International Conference on
   Robotics and Automation, April, 1986, San Francisco, California.
      An autonomous free-flying robot has been recommended by the NASA
   Advanced Technology Advisory Committee (ATAC) for proximity servicing
   outside the Space Station. In order to perform Space Station proxi-
   mity servicing, the free-flying robot must have an autonomous rendez-

vous capability. This includes defining and planning trajectories to visually located targets, stationkeeping, and defining and planning arm/ end effector trajectories for the execution of servicing tasks. The robot's trajectory planner generates trajectories in the constrained world space, expressed in generalized coordinates, (a combination of end effector and mobile base position, rate and force), and then uses an inverse kinematic and dynamic submodule to translate those trajectories into corresponding command trajectories in joint-mobile base jet space.

Avionics Systems Division

1. Blissit, James A., Jr. (Charles Stark Draper Laboratory): An Adaptive Guidance Algorithm for an Aerodynamically Assisted Orbital Plane Change Maneuver. CSDL-T-902. NASA CR-177296, May 1986, 229 pp.
     Using analysis results from the POST trajectory optimization program, an adaptive guidance algorithm is developed to compensate for density, aerodynamic, and thrust pertubations during an atmospheric orbital plane change maneuver. The maneuver offers increased mission flexibility along with potential fuel savings for future reentry vehicles. Although designed to guide a proposed NASA Entry Research Vehicle, the algorithm is sufficiently generic for a range of future entry vehicles. The plane change analysis provides insight suggesting a straight-forward algorithm based on an optimized nominal command profile. Bank angle, angle-of-attack, engine thrust level, and ignition and cutoff times are modulated to adjust the vehicle's trajectory to achieve the desired end-conditions. A performance evaluation of the scheme demonstrates a capability to guide to within 0.05 degrees of the desired plane change and five nautical miles of the desired apogee altitude while maintaining heating constraints. The algorithm is tested under off-nominal condition of ±30% density biases, mwo density profile models, ±15% aerodynamic uncertainty, and a 33% thrust loss and for various combinations of these conditions. Based on fuel comparisions with results of the optimization program, the guidance scheme offers a near optimum solution without the complexity of real-time optimization.

2. Brock, Larry D.; and Lala, Jaynarayan (Charles Stark Draper Laboratory): Advanced Information Processing System: Status Report. Presented at the National Aerospace Electronics Conference (NAECON), May 19-23, 1986, Dayton, Ohio.
     The Advanced Information Processing System (AIPS) is designed to provide a fault tolerant and damage tolerant data processing architecture for a broad range of aerospace vehicles. The AIPS architecture also has attributes to enhance system effectiveness such as graceful degradation, growth and change tolerance, and integrability. Two key building blocks being developed by the AIPS program are a fault and damage tolerant processor and communication network. A proof-of-concept system is now being built and will be tested to demonstrate the validity and performance of the AIPS concepts.

3. Chevers, Edward S.: Ada versus LISP versus Prolog. Presented at the SAE Control and Guidance Systems Conference, September 3-5, 1986, Minneapolis, Minnesota.
     LISP and Prolog are the primary languages used for development of artificial intelligence and expert system program applications. For the NASA Space Station Program, Ada has been designated the language for operational software. This includes network operating system, system software, and all flight applications. One of the features of the Space Station will be advancements in the field of automation and robotics. Expert system technology is expected to be a major consideration in the design and maintenance of Space Station subsystems. This presentation discusses the three languages, Ada, LISP, and Pro-

log, in the context of Space Station requirements. Plans for a Space Station automation test bed will also be described.

4. Chevers, Edward S.: Concept for Space Station Avionics Integration/ Verification/Checkout/Maintenance. Presented at the SAE Aerospace Control and Guidance Meeting, March 13, 1986, Salt Lake City, Utah.

    As NASA begins development of the Space Station, the long term implications of onboard test and checkout are being addressed as part of the early design definition phase. This paper presents a concept that satisfies all aspects of subsystem and subsequent system level development and integration from the factory to onorbit maintenance, modification, and upgrade. Both hardware and software requirements are considered in the concept.

5. Chevers, Edward S.: Space Station Integration and Verification Concepts. Presented at the AIAA/IEEE Digital Avionics Systems Conference, October 13-16, 1986, Fort Worth, Texas.

    One of the major study tasks in the early design definition phase of the Space Station is the long term implications of onboard test and checkout techniques. This paper describes a concept that begins with subsystem and subsequent system level development and integration in the factory and continues on to onorbit maintenance, modification, and upgrade. Requirements for both hardware and software are considered in the concept.

6. Chevers, Edward S.: Space Station Requirements for Common APSE Interface Standard (CAIS). Presented at the KIT/KITIA Working Group Meeting, January 13, 1986, San Diego, California.

    The Space Station data system architecture is based on a decentralized concept with independent processing nodes performing specific subsystem functions in relatively autonomous fashion. Initially, all processors will be identical in both hardware and system support software. Contractors will design, code, and validate application software on these standardized and homogeneous flight computer resources. After the Space Station has reached a permanently manned operational status, some portions of the data management system will be upgraded with new hardware and/or software as requirements change. To support this development, a standard interface for commercial software tools must be defined to allow portability of tools to several different host computers. There must also be unique modeling tools defined which permit multiple flight computers operating in parallel on common data streams to be emulated on one development host. This distributed architecture and multitarget interoperability are requirements which must be addressed by the KIT/KITIA. This presentation describes the Space Station design, software tools environment, and validation procedures.

7. Chevers, Edward S.: Status Report on NASA-JSC Ada Development Activities. Presented at the ACM SIGADA (Special Interest Group-Ada) Meeting, July 23, 1986, Pittsburgh, Pennsylvania.

    The NASA Space Station Program has selected Ada as the language of choice for all operational software. However, there are some concerns relative to the ability of existing compilers and program environments to generate codes for target flight computers which must operate in

real time. The Johnson Space Center and University of Houston/Clear
Lake, in conjunction with the local aerospace contractor community,
have been conducting studies to resolve these issues and other po-
tential problems for the Space Station. This presentation defines the
concerns with the Ada language, describes studies which are in pro-
gress or have been completed, and presents additional areas requiring
resolution.

8. Cox, Kenneth J.: Space Station GN&C Design and Development.
    Presented at the SAE Aerospace Control and Guidance Systems Committee
    Meeting, March 12, 1986, Salt Lake City, Utah.
    The Space Station Program has moved significantly into the Phase B
    program design. This presentation discusses ongoing activities asso-
    ciated with the guidance, navigation, and control (GN&C) design of the
    core Space Station. A description of the dual keel configuration is
    first presented. The present GN&C system design is described, includ-
    ing both system architecture and software functions. Significant in-
    terface areas with the GN&C design are discussed. Finally, important
    areas of emphasis are outlined as part of future activities.

9. Gilbert, David W.: System Level Verification Applying the Space
    Shuttle Experience to the Space Station. Presented at the Annual AAS
    Rocky Mountain Section Guidance and Control Conference, February 1-5,
    1986, Keystone Village, Colorado.
    The success of the Space Shuttle avionics systems is due in large
    measure to the effectiveness of the system-level verification testing
    required prior to each mission. Applying this experience to the Space
    Station does not appear to be practical or even possible in some re-
    spects. A new approach is needed which accommodates the unique pro-
    gram characteristics and takes advantage of the 15-year growth in
    technology between programs. This paper reviews some of the Shuttle
    experience and presents a new approach for consideration by the Space
    Station Program. It includes as an example the important role that
    flight control/structural dynamics testing played in the Shuttle Pro-
    gram and how this would be accomplished for the Space Station. It ap-
    pears to be the way for the future. The question is, is it timely for
    the Space Station?

10. Humble, Ronald W. (Lockheed Engineering and Management Services
     Company): Systems Engineering Simulator/Tethered Satellite System.
     Presented at the Tether Dynamics Simulation Workshop, 1st Inter-
     national Conference on Tethers in Space, September 1986, Arlington,
     Virginia.
     The tethered satellite system (TSS) is modeled on the systems engi-
     neering simulator (SES) at the Johnson Space Center to examine "man in
     the loop" critical TSS mission phases and to study missions where high
     fidelity, real time Shuttle Orbiter/payload interactions are required.
     The Space Shuttle Orbiter is modeled as a rigid body with six degrees
     of freedom (DOF). Virtually all mission important functions are simu-
     lated and continuously validated. The tethered satellite is also
     modeled as a rigid body with 6 DOF. The two bodies are constrained by
     an elastic, massless tether which adds one more DOF, making a total of
     13 DOF. The satellite model has an attitude control system which
     controls motion about the tether axis using gaseous nitrogen thrus-

ters. In addition, two inline thrusters are modeled to provide additional tether tension at close ranges. The satellite inertial measurement unit and tether deployer system are modeled as perfect systems.

11. Mallary, William E.: Space Station Data Management System Baseline Definition. Presented at WINCON '86, February 26-28, 1986, Costa Mesa, California.

    This presentation provides a summary description of the Space Station Data Management System (DMS) baseline definition which will be used as the basis for preliminary design of the DMS as well as for Space Station systems and subsystems which interface with the DMS system or use DMS components in their design. The definition includes descriptions of the DMS hardware and software components, user services, and interfaces. The relationships and allocations of responsibilities between the DMS and other subsystems for issues such as commonality, standards, data privacy, fault/redundancy management, and command management are also described.

12. Nagle, Gail A. (Charles Stark Draper Laboratory): An Ada Implementation of the Network Manager for the Advanced Information Processing System. Presented at the 1st International Conference on Ada Programming Language Applications for the NASA Space Station, June 2-5, 1986, Houston, Texas.

    The Advanced Information Processing System (AIPS) is a data processing architecture designed to meet the reliability requirements of space vehicle applications. The AIPS architecture is highly modular. The needs of a specific application can be met by selecting components from a set of hardware building blocks and software system services. One such building block is a fault and damage tolerant input/output network which allows a data processing element to communicate serially with I/O devices. The system service which is responsible for the reliable operation of an I/O network is the I/O Network Manager. The Charles Stark Draper Laboratory is presently building an AIPS proof-of-concept prototype. High level design objectives of the network manager software for the prototype include transparency to network users, adaptability to dynamically changing system configurations, and modularity. Ada language constructs have been found which support these design goals.

13. Pace, Walter H., Jr. (TRW): A Recursive Model for Software Development. Presented at the Orbital Projects Data and Software Systems Commonality Workshop, October 28-30, 1986, Houston, Texas.

    The software development model proposed decomposes the project by successive refinement into a hierarchy of subprojects. Each subproject implements one of the functions required, making use of the products of subprojects below it in the hierarchy. A project template is proposed that is used recursively to schedule the activities in each of the subprojects and of the project as a whole. The underlying philosphy of the model is that everything should be done as soon as possible. In particular, coding at each level of refinement is done immediately after the design for that level and before the designs at the next level. That is, both design and code are interleaved in a top-down manner. A side effect of using this model is that the effort

required in a planned software project can be estimated from a pre-
dicted hierarchy of functions rather than from predicted lines of
code.

14. Racine, Roger: (Charles Stark Draper Laboratory): Transparent Ada
    Rendezvous in a Fault Tolerant Distributed System. Presented at the
    1st International Conference on Ada Programming Language Applications
    for the NASA Space Station, June 2-5, 1986, Houston, Texas.
       Previous papers on Ada for distributed systems assumed an absence of
    fault tolerance. In that case, it is difficult to implement a rendez-
    vous scheme without multiple transmissions over the network to ensure
    processors remain active throughout the wait for the rendezvous. In a
    fault tolerant system, this problem does not exist. If one of the
    processors in an FTP fails, the fault is detected. If the fault can
    be masked, processing continues normally. If it is not possible to
    isolate the fault, the FDIR will reconfigure the system such that
    functions on the failed FTP are run on a different FTP. In either
    case, the communication can proceed successfully. For this type of
    system, it is possible to design an efficient communication service to
    implement the Ada rendezvous. An Ada design for the communications
    system is presented, including a description of the services provided
    in all seven layers of an International Standards Organization (ISO)
    open systems interconnect (OSI) model communications system. The
    system capabilities (hardware and software) that allow this communi-
    cation system are also described.

15. Redding, D.; Adams, N. (Charles Stark Draper Laboratory); and
    Kubiak, Edward (JSC): Linear-Quadratic Stationkeeping for the STS
    Orbiter. Presented at the AIAA/AAS Meeting, August 18-20, 1986,
    Williamsburg Virginia.
       The paper presents an automatic controller for Space Shuttle Orbiter
    stationkeeping and formation keeping. The controller uses a feed
    forward loop for nonequilibrium set point and maneuver transients, and
    a discrete-time, linear-quadratic regulator for feedback control. The
    paper describes the selection of design parameters, such as sample
    time and quadratic cost matrices, to provide good performance in the
    presence of sensor or noise and actuator granularity. Results show
    good performance with the current orbiter sensors; extremely precise
    control is demonstrated using enhanced sensors.

16. Volansky, Elaine (TRW): Simulation of the Space Station Data System
    Real-Time Control Function. Presented at the 14th IASTED Interna-
    tional Conference and Exhibition, June 4-6, 1986, Vancouver, Canada.
       The Space Station will serve as a center where specialists from
    many countries can converge with the common goal of scientific dis-
    covery. Towards this end, the Space Station Data System (SSDS) must
    provide responsive services to users and ensure operational independ-
    ence while supporting system safety. It does this via the real-time
    control function which manages user commands and limited flight re-
    sources such as power, thermal dissipation and attitude position.
    Real-time control is responsible for overall coordination and control
    of on-board core systems and for command and resource management ser-
    vices in support of payload operations. This paper focuses on the
    discrete event simulation effort undertaken as part of the proof of

design for the SSDS real-time control function. The function is described and parametric studies performed to assess disk and processor performance are discussed.

17. Volansky, Elaine; and Roberts, Charles R. (TRW): A Design Approach for the Space Station Data System. Presented at the 1986 Aerospace Applications Conference, February 1-8, 1986, Steamboat Springs, Colorado.

The Space Station data system (SSDS) design presented provides a data system architecture which simultaneously supports core operational and user payload access requirements and offers a number of advantages over user interfaces to traditional systems (1) The space and ground network node is viewed as a single entity, greatly reducing the traditional discontinuity between space and ground system designs. (2) Uniform, standardized interfaces to this node are provided to all users, to all payloads, and to platforms replacing customized interfaces. (3) A data-driven network node is responsive to data as it is received rather than requiring preconditioned uplink and downlink scheduling. The primary means of implementation of this design approach is through the data delivery service (DDS), which provides communication intelligence, space/ground core/user integration, and is the major component in the end-to-end transparent user access. Its services are available to all elements of the Space Station Program without regard to their physical location or their traditional functional allocation. Data Delivery supports multiple missions and multiple users. A unified data delivery ground portion of the network node includes both downlink and uplink in a symmetric manner. The identical services provided to user elements on the ground are provided to user elements in space.

Propulsion and Power Division

1. Bemis, R.; and Perry, D. L. (Rockwell International Corporation): Orbital Consumables Resupply Requirements Impact on the Evolution of the Orbital Spacecraft Consumables Resupply System. Presented at the AIAA /ASME/SAE/ASEE 22nd Joint Propulsion Conference, June 16-18, 1986, Huntsville, Alabama.

   Development of the orbital spacecraft consumables resupply system (OSCRS) is an essential and logical step in the progression of man's utilization of space. Present and future space assets which would benefit from resupply provide specific design related requirements. These requirements integrated with the roles OSCRS is to play in the industrialization of space provide an optimized utilitarian vehicle. Specific areas of requirements and their impact on OSCRS design include the potential user resupply requirements and mission scenarios, unique user spacecraft handling needs and other OSCRS uses and the accompanying integration concerns. These and other elements and their effect on the evolution of an OSCRS design are discussed. The paper closes with a focus on the influence the bipropellant resupply scenario has on the design and development of the generic resupply tanker.

2. Boyd, William C.: Uprated OMS Engine for Upper Stage Propulsion. Presented at the 1986 JANNAF Propulsion Meeting, August 26-28, 1986, New Orleans, Louisiana.

   The baseline orbital maneuvering engine (OME) of the Space Shuttle is a pressure-fed engine utilizing storable propellants. A significant performance uprating of this engine can be achieved through the use of a gas generator-driven turbopump that increases OME operating pressure. A higher pressure engine can have a greater nozzle expansion ratio in the same envelope and at the same thrust level, giving increased engine Isp. The results of a pre-development component demonstration program being pursued at the Johnson Space Center are presented. These include the preferred uprated OME configuration, descriptions of test hardware, and discussion of test results. Tests and analyses confirm the capability of the concept to meet or exceed performance and life requirements. Storable propellant upper stage concepts using an uprated OME are also discussed. Analyses indicate this high performing engine can be used in a storable propellant upper stage to achieve a "payload to geosynchronous earth orbit (GEO)" capability comparable to existing cryogenic stages.

3. Brasher, Warren L.; and Boyd, William C.: Uprated OMS Engine Status and Future Application. Presented at the AIAA/ASME/SAE/ASEE 22nd Joint Propulsion Conference, June 16-18, 1986, Huntsville, Alabama.

   The baseline orbital maneuvering engine (OME) of the Space Shuttle has the potential for significant performance uprating, leading to increased Shuttle payload capability. The approach to OME uprating that is being pursued at the Johnson Space Center is the use of a gas generator-driven turbopump to increase OME operating pressure. A higher pressure engine can have a greater nozzle expansion ratio in the same envelope and at the same thrust level, giving increased engine Isp. The results of trade studies and analyses that have led to the preferred uprated OME configuration are presented. The significant ac-

complishments of a predevelopment component demonstration program are also presented, including descriptions of test hardware and discussion of test results. It is shown that testing to date confirms the capability of the preferred uprated OME configuration to meet or exceed performance and life requirements. Potential future activities leading to a full-scale development program are presented. The capability for the uprated OME to be used in future storable propellant upper stages is also discussed.

4. Eberhardt, R. N.; Tracey, T. R.; and Bailey, W. J. (Martin Marietta Denver Aerospace): Orbital Spacecraft Resupply Technology. Presented at the AIAA/ASME/SAE/ASEE 22nd Joint Propulsion Conference, June 16-18, 1986, Huntsville, Alabama.

The life of many spacecraft can be significantly extended if they are resupplied in orbit with propellants and pressurant gases. The resupply can take place from the Space Shuttle, the orbital maneuvering vehicle (OMV) which can move between the Space Shuttle and an orbiting Space Station, or from depot supply tanks at the Space Station. In addition, a space-based OMV and the Space Station both require on-orbit resupply themselves. The OMV has a bipropellant (NTO, MMH) propulsion system, and hydrazine and gaseous nitrogen systems for station proximity operations. Fluids such as freon, ammonia, methanol, superfluid helium, gaseous nitrogen, and water may need to be resupplied to the Space Station for subsystem working fluid replacement or payload/experiment fluid replenishment. Candidate fluid transfer methods and possible pressurant gas transfer methods are discussed, and relative advantages/disadvantages presented along with a technology status assessment of each. Fluid management technology issues that can drive the design of on-orbit resupply systems and capabilities are specifically addressed. Preliminary designs for both monopropellant and bipropellant orbital spacecraft consumables resupply systems (OSCRS) are presented.

5. Faget, Nanette M.: Materials Compatibility Issues Related to Thermal Energy Storage for a Space Solar Dynamic Power System. Presented at the Intersociety Energy Conversion Engineering Conference, August 25-29, 1986, San Diego, California.

Increasing electrical power requirements have made a solar dynamic power system (SDPS) a serious contender for the electrical power generating system for the Space Station because of its potential advantages compared to a photovoltaic power system at higher power levels. An SDPS converts solar energy into electricity by utilizing rotating heat engines. A thermal energy storage (TES) system is required to supply the heat engine with a constant temperature source of heat energy during the eclipse portion of a low Earth orbit. The TES system operates by using the latent heat of energy of a phase change material to absorb energy at essentially constant temperature during the sunlit portion of the orbit and then release this energy to the engine at the same temperature for use during the eclipsed portions. Currently, the TES system is considered to be the weakest link in the SDPS with regard to technology readiness. One reason for this is that the long term (5-10 years) compatibility between the TES phase change material and its container has yet to be proven. Materials compatibility testing is underway at the Johnson Space Center to determine whether a TES

system can meet the Space Station long life and reliability require-
ments. Preliminary test results and conclusions from this test pro-
gram are presented.

6. Gorin, Barney (Fairchild Space Company): Mission Requirements and De-
sign Definition for an Orbital Consumables Resupply System (OSCRS).
Presented at the AIAA/ASME/SAE/ASEE 22nd Joint Propulsion Conference,
June 16-18, 1986, Huntsville, Alabama.

The rapidly developing capability of the Space Shuttle to repair sa-
tellites on orbit will soon be extended to include other types of ser-
vice, including the replenishment of consumables, many of which will
be liquids and gases. An integrated system must be developed which is
capable of delivering all of the necessary fluids to orbit in a safe,
reliable, cost effective manner. An overview of the general require-
ments for such a system is presented, including a traffic model for
all fluids. A set of detailed resupply system requirements is devel-
oped for those fluids which represent the most immediate market for on
orbit resupply.

A preliminary design is described for a resupply system for mono-
propellant hydrazine, with specific application to the GRO spacecraft
refueling planned for 1991 and the requirements which evolve from the
traffic model. A similar conceptual design is presented for a system
suitable for use with earth storable bipropellants.

7. Griffin, John W.: Development of Orbital Fluid Resupply. Presented
at the AIAA/ASME/SAE/ASEE 22nd Joint Propulsion Conference, June 16 -
18, 1986, Huntsville, Alabama.

On-orbit resupply of fluids will be essential to the evolving gene-
ration of large and long life orbital stations and satellites. Al-
though sizes of the fluid resupply tankers to accomplish these tasks
may vary considerably depending on the specific application, the
transfer/servicing technologies and hardware design concepts for a
specific fluid should be basically the same. This paper discusses the
resupply of concept options presently envisioned, the technology and
hardware problems projected to implement these concepts, and the pro-
posed, as well as ongoing, NASA activities to resolve these problems.

8. Hackler, Irene M.: Alkaline RFC Space Station Prototype "Next Step
Space Station." Presented at the Intersociety Energy Conversion Engi-
neering Conference, August 25-29, 1986, San Diego, California. Pub-
lished in Proceedings, Vol. III, pp. 1903-1908.

It is currently expected that the initial power source will be pho-
tovoltaic solar arrays. Since the Space Station is eclipsed during
roughly one third of the orbit and the solar arrays do not produce
electricity during this time, some sort of energy storage system (ESS)
is necessary. One candidate technology is the regenerative fuel cell
(RFC). A joint advanced development program was initiated by the
Lewis Research Center and the Johnson Space Center to design, manu-
facture and integrate a regenerative fuel cell Space Station Prototype
(RFC SSP). Improvements for the RFC SSP are being made in both the
water electrolysis system and the fuel cell. The RFC SSP incorporates
long-life fuel cell technology, increased cell area for the fuel
cells, and high voltage cell stacks for both units. Microprocessor
control and monitoring hardware and software are also being incorpor-

ated. This unit will be tested on the ground in a thermal-vacuum environment at a nominal 10 kW level. Space Station condition will be simulated to prove that such a closed cycle system is efficient, practical, and capable of handling all envisioned Space Station power system operating conditions.

9. Hermanson, Lynn A. (Ball Aerospace Systems); and Snyder, H. A. (University of Colorado-Boulder, and Ball Aerospace Systems): Pressure Induced Radial Oscillations of Large Bubbles. Presented at the 39th Annual Meeting of the American Physical Society Fluid Dynamics Section, November 23-25, 1986, Columbus, Ohio.

   Several studies have been published on the oscillation of a bubble in an imposed pressure field. These studies are not applicable to large bubbles because the approximations used are chosen to model small bubbles. Free bubbles ranging from 10 to 200 cm in diameter occur in low gravity applications. A linear analysis of the coupled dynamic, heat transfer, and diffusion equations is presented. The model is designed to be accurate for large bubbles and moderate to low frequencies. Both pressurized and vapor bubbles are treated. Graphs showing numerical evaluation of the theoretical formulas are displayed.

10. Hoffman, William C., III: Electrostatic Discharge Sensitivity Test Results for Three Composite Propellants. Presented at the 1986 JANNAF Propulsion Meeting, August 26-28, 1986, New Orleans, Louisiana.

    Premature ignition of composite propellants has received increased scrutiny due to a solid rocket accident which was attributed to an electrostatic discharge within the propellant grain. A test program was initiated to investigte propellant sample size and temperature effects. Results show that propellant ignition using the sample sizes and test configuration described was not readily produced. The breakdown strength of the propellants decreased with decreasing temperature. The resistance of the propellants was observed to increase with decreasing temperature.

11. Hoffman, William C., III: Increased Accuracy of Squib Bridgewire Measurements Using a 4 Contact 22 - Pin Connector. Presented at the 11th International Pyrotechnics Society Seminar, July 11, 1986, Vail, Colorado.

    The production of the NASA Standard Initiator (NSI), a squib used to start most pyrotechnic events on the Space Transportation System, involves the measurement of the unit's bridgewire resistance. The measured value is influenced by contact resistance due to surface contaminants between the measurement connector and NSI. Fluctuations in resistance would sometimes result in NSI rejection due to specification deviations. Such deviations were attributable to contact resistance variation. Minimizing contact resistance through the use of the 4 contact 2 pin connector has been demonstrated in test and is now being implemented in the production of NSI's.

12. Kiefel, Erlinda R.; Martino, M. K.; Rudolph, L. K.; and Fester, Dale A. (Martin Marietta Denver Aerospace): Space Station Tethered Refueling Facility Operations. Presented at the AIAA/ASME/SAE/ASEE 22nd Joint Propulsion Conference, June 16-18, 1986, Huntsville, Alabama.

The space-based orbit transfer vehicle (OTV) will require a large cryogenic fuel storage facility at the Space Station. An alternative to fuel storage onboard the Space Station is a tethered orbital refueling facility (TORF) which is separated from the Space Station by a sufficient distance to induce a gravity gradient to settle the propellants. Facility operations are a major concern associated with a tethered LO_2/LH_2 storage depot. A study was carried out to analyze the preferred TORF deployment direction (up or down with respect to the Space Station) and whether the TORF should be permanently or intermittently deployed. The analyses included safety, contamination, rendezvous, servicing, transportation rate, communication, and viewing. An upwardly, intermittently deployed facility is the preferred configuration for a tethered cryogenic fuel storage.

13. Kiefel, Erlinda R.; Rudolph, L. K.; and Fester, D. A. (Martin Marietta Denver Aerospace): Comparison of a Tethered to a Zero-Gravity Refueling Facility. Presented at the International Conference on Tethers in Space, September 17, 1986, Arlington, Virginia.

   The space-based orbital transfer vehicle (OTV) will require a large cryogenic fuel storage facility at the Space Station. An alternative to fuel storage onboard the Space Station is a tethered orbital refueling facility (TORF) separated from the Space Station by a sufficient distance to induce a gravity gradient to settle the propellants. Overall costs and benefits of a particular tethered facility design have been defined relative to a representative zero-gravity facility on the Space Station. Results indicate that the TORF hardware and operations costs are roughly 40% higher than the comparable zero-g facility costs. The cost difference becomes negligible when the fuel launch cost for the facility 10-year lifetime is included.

14. Kroll, Kenneth R.: Tether Implications On Space Station Gravity Level. Presented at the International Conference On Tethers In Space, September 17-19, 1986, Arlington, Virginia.

   Microgravity research of material processes, a primary application of the Space Station, imposes severe design requirements. A single tether will shift the center of gravity, placing a gravity gradient acceleration on the Space Station when deployed. Varying the length of opposing tethers can actively position the system center of gravity to compensate for changes in the mass distribution on the Space Station itself. This will allow more flexibility in the Space Station configuration and a more consistent gravity level. Similarly, opposing tethers can balance the acceleration produced by other tether applications to meet the mirogravity requirement. Another option is to deploy tether applications intermittently, so that a gravity gradient acceleration will only be produced on the Space Station for a short period of time, when experimentation can be stopped. Placing an automated laboratory on a tether elevator will enable processes to be expanded over a range of accelerations.

15. Snyder, Howard A. (University of Colorado-Boulder, and Ball Aerospace Systems); and Hermanson, Lynn A. (Ball Aerospace Systems): Distortion of A Large Spherical Bubble By Random Acceleration. Presented at the 39th Annual Meeting of the American Physical Society Fluid Dynamics Section, November 23-25, 1986, Columbus, Ohio.

Large bubbles in low levels of gravity are easily distorted by random acceleration of the storage tank. It is shown that the governing equation for the distortion is a special case of the Mathieu equation. Since solutions of the Mathieu equation are unstable, it is shown how the spectrum of the random acceleration affects instability and break-up of the bubble. Computer simulation is used to illustrate the results.

16. Teeter, Ronald R.; Crabb, Thomas M. (Astronautics Corporation of America); and Johnson, Leo R. (JSC): Lunar Based Propulsion Systems. Presented at the Symposium '86, September 22-24, 1986, Alantic City, New Jersey.

This paper summarizes the work to date on the lunar surface base propulsion systems study performed for Johnson Space Center. Results will include lunar propellant availability and associated processing techniques, and propulsion/vehicle system design concepts. These propellant supply and transportation concepts will then be addressed in terms of mission and traffic model trade studies and technology requirements.

17. Wagner, Howard A.: Scalloped Geometry Concentrator: An Error Tolerant Parabolic Solar Concentrator. Presented at the 1986 ASME Solar Energy Divison Conference, April 1986, Anaheim, California. Published in Proceedings.

The major disadvantage of parabolic solar concentrators is sensitivity to mirror surface slope errors and solar tracking errors. The sensitivities of a paraboloidal concentrator, a multifaceted paraboloidal concentrator, and a scalloped geometry concentrator to errors in surface slope and solar tracking accuracy were analyzed by a ray trace computer program. The analysis was performed for an 18-m (60 ft) diameter concentrator with a 1.05-rad (60°) rim angle. The scalloped geometry concentrator was found to be at least sensitive to surface slope errors and more tolerant of errors in solar tracking than the other concentrators. For example, if errors of 17 mrad (1°) in surface slope and of 17 mrad (1°) in solar tracking exist simultaneously, focal spots of 2.1 m (6.9 ft), 2.8 m (9.3 ft), and 0.49 m (1.6 ft) diameter are produced for the paraboloidal, multifaceted paraboloidal, and scalloped geometry concentrators, respectively.

Structures and Mechanics Division

1. Cross, J. B.; Spangler, L. H.; Hoffbauer, M. A.; Archuleta, F. A. (Los Alamos National Laboratory); Leger, Lubert; Visentine, James (JSC); and Hunton, Don E. (Air Force Geophysics Laboratory): High Intensity 5 eV O-Atom Exposure Facility for Material Degradation Studies. Presented at the IES 14th Space Simulation Conference, November 3-6, 1986, Baltimore, Maryland. NASA CP-2446, p. 209.

    An atomic oxygen exposure facility has been developed for materials degradation studies to provide (1) absolute reaction cross sections for use in engineering design problems, (2) formulations of reaction mechanisms for use in selection of suitable existing materials and design of new, more resistant ones, and (3) calibration of flight hardware (mass spectrometers, etc.) in order to directly relate experiments performed in low earth orbit to ground based investigations. The facility consists of (1) a cw laser sustained discharge source of O-atoms having a variable energy up to 5 eV and an intensity of between 10^{15}-10^{17} O-atoms s-1, cm-2, (2) an atomic beam formation and diagnostics system consisting of various stages of differential pumping, a mass spectrometer detector and a time-of-flight analyzer, (3) a spinning rotor viscometer for absolute O-atom flux measurements, and (4) provision for using the system for calibration of actual flight instruments.

2. Curry, Donald M.: Thermal Protection Systems - Past, Present, Future. Presented at the AIAA Oklahoma Section Meeting, May 15, 1986, Norman, Oklahoma.

    Significant progress in thermal protection system design has occurred since the first manned space flight of Mercury in May 1961 with its single use ablative thermal protection system (TPS) and the first Space Shuttle Orbiter flight in April 1981 with its multi-mission TPS. Currently, there is a great deal of interest in TPS systems for the aeroassisted orbital transfer vehicle (AOTV) being proposed for use between geosynchronous earth orbit stations and the low earth orbit Space Station. This presentation discusses the major material and design challenges associated with TPS, various TPS materials that are used, the different design approaches associated with each of the materials and the entry aerothermodynamic environment which plays a large role in TPS design. Specific TPS concepts used for the Mercury, Gemini and Apollo vehicles, Shuttle Orbiter, and proposed systems for AOTV's are discussed.

3. Curry, Donald M. (JSC); Rochelle, W. C.; Chao, D. C.; and Ting, P. C. (Rockwell International): Space Shuttle Orbiter Nose Cap Thermal Analysis. Presented at the AIAA Aerospace Sciences Meeting, January 6-8, 1986, Reno, Nevada. AIAA Paper No. 86-0388.

    The results of a Shuttle Orbiter nose cap entry aeroheating assessment, thermal analysis and correlation of flight data using multidimensional thermal math mmodels (TMM's) and a chemically reacting boundary layer program are described in this paper. The object of this study was to verify and revise, if required, the nose cap design heating methods and the TMM's used for flight certification. Flight temperature measurements from two orbiter vehicles, Columbia and Chal-

lenger, have been used in this analysis and provide the basis for ver-
ification and correlation of the aerothermodynamic environment. Nose
cap thermal response predictions, using TMM's verified from certifica-
tion tests, show that the aerothermodynamic environment can be satis-
factorily predicted using accepted analytical methods.

4. Forman, Royce G.: Developments in NASA Fracture Control Methodology.
   Presented at the American Society for Testing and Materials Biannual
   Meeting, April 28-May 2, 1986, Charleston, South Carolina.
   A number of efforts are underway by NASA to further develop fracture
   control methodology. These efforts have grown, in part, from the need
   for a reliable and consistent methodology for Space Shuttle payloads
   and, in the coming years, for the Space Station. The important recent
   accomplishments in these efforts have been: 1) formation of the NASA
   Fracture Control Analytical Methodology Panel, 2) development of the
   NASA/FLAGRO computer program, 3) development of the computer data base
   for fracture mechanics material properties, and 4) writing of the
   guidelines document for fracture control procedures on Space Shuttle
   payloads. Brief discussion is given on these four topics and future
   planned activities.

5. Hunton, D. E.; Trzcinski, E. (Air Force Geophysics Laboratory); Cross,
   J. B.; Spangler, L. H.; Hoffbauer, M. H.; Archuleta, F. H. (Los Alamos
   National Laboratory); and Visentine, James T. (JSC): Mass Spectrom-
   eters and Atomic Oxygen. Presented at the NASA Workshop on Atomic
   Oxygen Effects, November 10-11, 1986, Pasadena, California.
   The likely role of atmospheric atomic oxygen in the recession of
   spacecraft surfaces and in the Shuttle glow has revived interest in
   the accurate measurement of atomic oxygen densities in the upper at-
   mosphere. The Air Force Geophysics Laboratory is supplying a quad-
   rupole mass spectrometer for a materials interactions flight experi-
   ment being planned by the NASA Johnson Space Center. The mass spec-
   trometer will meaure the flux of oxygen on test materials and will al-
   so identify the products of surface reactions. The instrument will be
   calibrated at a new facility for producing high energy beams of atomic
   oxygen at the Los Alamos National Laboratory. This paper summarizes
   plans for these calibration experiments.

6. Hunton D. E.; Trzcinski, E.; (Air Force Geophysics Laboratory); Cross,
   J. B.; Spangler, L. H.; Hoffbauer, M. H.; and Archuleta, F. H. (Los
   Alamos National Laboratory); and Visentine, James T. (JSC): Quadru-
   pole Mass Spectrometer for Space Shuttle Applications: Flight Capa-
   bilities and Ground Calibration. Presented at the 18th International
   SAMPE Technical Conference, October 7-9, 1986, Seattle, Washington.
   The Air Force Geophysics Laboratory flew a quadrupole-type mass
   spectrometer on STS-4 to measure concentrations of positive ion and
   neutral species with high temporal and spatial resolution. In prep-
   aration for future flights, the instrument is being calibrated at a
   new atomic oxygen beam facility at the Los Alamos National Laboratory.
   A high energy (5 eV) atomic oxygen beam is produced using a continuous
   optical discharge technique. An oxygen/carrier gas plasma, pumped by
   a high power cw CO_2 laser, is expanded through a supersonic nozzle.
   The resulting beam has sufficiently high flux and velocity to simulate
   orbital conditions. The response of the flight mass spectrometer will

be compared to measurements made with other beam diagnostic tools to determine the sensitivity of the mass spectrometer to atomic oxygen. The calibrated instrument will be flown as part of the Johnson Space Center Evaluation of Oxygen Interactions with Materials (EOIM)-III experiment to measure ambient oxygen density and identify the products of oxygen-surface reactions.

7. Johnson, D. W. (LTV Missiles and Electronics Group); Curry, Donald M. (JSC); and Kelly, R. E. (Rockwell Internation): Space Shuttle Orbiter Leading Edge Structural Design/Analysis and Material Allowables. Presented at the AIAA/ ASME/ASCE/AHS 27th Structures, Structural Dynamics, and Materials Conference, May 19-21, 1986, San Antonio, Texas. AIAA Paper No. 86-0949-CP.

    Reinforced carbon-carbon (RCC), a structural composite whose development was targeted for the high temperature reentry environments of reusable space vehicles, has successfully demonstrated that capability on the Space Shuttle Orbiter. This paper deals with the characterization testing, structural analyses, full-scale qualification testing, and flight certification of this state-of-art composite for the Orbiter. Achievement of the program goals required detailed coordination of the design allowables, the manipulation of the test data into usable forms, and the analytical verification process. Included are discussions of the engineering decisions pertaining to the development of a design allowable data base and the eventual certification of this exceptional material for structural applications on a multimission space vehicle.

8. Leger, Lubert J.; Ehlers, Horst; and Jacobs, Stephen: Space Station Contamination Considerations. Presented at the 14th Space Simulation Conference, November 3-6, 1986, Baltimore, Maryland. NASA CP-2446, p. 341.

    This paper addresses the external induced environment generated by Space Station activity or more specifically by gases, particles, and light background. These contaminant species must be controlled if sensitive systems such as solar energy collectors or science experiments exposed to the external environment are to function properly. The requirements, discussed in detail, generally set limits on the level of gas species, matter deposited on surfaces, and light background levels over the various spectral regions. They also address environment monitoring and contamination controls during manufacturing. Limits on effluent release and system leakages are in turn derived from these requirements. Overall, the process provides an optimum balance between laboratory/environmental life control system fluid management problems and contamination sensitive external systems. Once requirements are established, Space Station contamination performance, which is analytically assessed, can be compared with needs, and design trades can be directed to optimum system design. Performance studies conducted to date indicate that the core Station can provide an adequate environment for astronomy measurements if contamination effects are considered early in design. Results of these studies and associated design solutions which define the preliminary Space Station environment are presented.

9. Leger, Lubert J.; and Visentine, James T.: A Consideration of Atomic Oxygen Interactions with the Space Station. <u>Journal of Spacecraft and Rockets</u>, Vol. 23, No. 5, September-October 1986, pp. 505-511.

   Significant surface interactions which are very likely due to exposure to atomic oxygen in low Earth orbital environment have been observed on recent space flights. These interactions are manifested as surface recession and, therefore, mass loss, and appear to arise from oxidation of the materials involved. A computer model has been developed to compute atomic oxygen fluence (total integrated flux) for a generalized spacecraft in orbital flight based on mass spectrometer and incoherent scatter (MSIS) ambient density predictions. Calculations for Space Station surfaces using this model have been made. Assuming a constant altitude flight strategy, total fluence on ram-facing surfaces during a complete solar cycle is $1.2x \ 10^{22}$ atoms/cm^2 and $6.7x10^{21}$ atoms/cm^2 for solar-facing surfaces with both sides exposed. Using material reactivities for composite materials and thin films developed from flight experiments, total recession for ram and solar inertial surfaces will be 0.036 cm(14 mils) and 0.020 cm(8 mils), respectively, per solar cycle. For a station life of 30 years, approximately three cycles will be experienced; the resulting recession appears unacceptable for certain surfaces. These effects must be accounted for if long-lived operation is to be expected.

10. Leger, Lubert J.; and Visentine, James T.: Protecting Spacecraft From Atomic Oxygen. <u>Aerospace America</u>, Vol. 24, No. 7, pp. 32-35, July 1986.

    Various coatings are being developed to protect sensitive materials. Fluorpolymers or metal oxides codeposited with small amounts of polytetrafluorethylene would be applied directly to space structures such as polyimide solar array substrates. Metallized foils would protect composite tubes, and conversion coatings with the correct optical properties would become integral parts of basic structures. To intelligently plan protection of long-duration satellites, we must augment the limited data base on atomic oxygen interactions with materials in low Earth orbit, using both Shuttle flight experiments and ground-based facilities. Space Station design is imminent, and our understanding of such interactions is critical to its success.

11. Leger, Lubert J.; Visentine, James T.; and Santos-Mason, Beatrice: Selected Material Issues Associated with Space Station. Presented at the 18th National SAMPE Technical Conference, October 6-9, 1986, Seattle, Washington. Published in <u>SAMPE Quarterly</u>, Vol. 18, No. 2, January 1987, pp. 48-54.

    The requirement for long life in the range of 30 years for structural components and 20 years for power systems requires new considerations in material selection. Additionally, extended exposure to large amounts of atomic oxygen from the Earth's rarified atmosphere has recently been shown to be a very significant degrading factor for spacecraft materials, even generating completely new requirements for coatings used on exterior surfaces. Considerations of Shuttle lift capabilities, the large amount of mass associated with Space Station components, and the low mechanical loads imposed on components result in thin-walled structures made from organic matrix/carbon fiber composite materials. These materials have to be stable not only for over

175,000 thermal cycles, but also for 30 years in the atomic oxygen environment. Hardware impacts and solutions being developed for Space Station applications are discussed.

12. Leger, Lubert J.; Visentine, James T.; Santos-Mason, Beatrice; and Kuminecz, Jerome: Review of Low Earth Orbit (LEO) Flight Experiments. Presented at the NASA Workshop on Atomic Oxygen Effects, November 9-11, 1986, Pasadena, California.

It is evident from previous Space Shuttle flights that the low Earth orbital (LEO) environment interacts with spacecraft surfaces in significant ways. One manifestation of these interactions is recession of organic polymer-based surfaces presumably due to oxidation by atomic oxygen, the major component of the LEO environment. Experiments have been conducted on many of the Space Shuttle flights to measure reaction rates and effects of various parameters on reaction rates. Flight experiments conducted on Space Shuttle flights 5, 8, 11 and 41G have yielded quantitative data while other flights provided only qualitative or limited quantitative data. Surface recession on these flights indicates reaction rates in the range of $2\text{-}3 \times 10^{-24} cm^3/atom$ for organic polymers. Application of these rates to Space Station exposure for main components suggests as much as 0.3 to 0.4 cm of recession will occur for forward facing surfaces. Such effects dictate the need for lightweight durable coatings to protect susceptible materials.

13. Rochon, Brian V.; and Scheer Steven A. (Lockheed Engineering and Management Services Company): Crew Motion and Activity Effects on the Space Station. Presented at the Workshop on Structural Dynamics and Control Interaction of Flexible Structures, April 22-24, 1986, Huntsville, Alabama.

Among the significant sources of internal disturbances that must be considered in the design of Space Station control systems are the loads induced on the structure from various crew activities. Flight experiment T013, flown on the second manned mission of Skylab, measured force and moment time histories for a range of preplanned crew motions and activities. This experiment has proved itself invaluable as a source of on-orbit crew induced loads that has allowed a Space Station forcing function database to be built. This will enable forced response such as accelerations and deflections, attributable to crew activity, to be calculated. The flight experiment, resultant database and structural model preprocessor, analysis examples and areas of continued research are described.

14. Shivakumar, V. (Lockheed-Engineering and Management Services Company); Forman, Royce G. (JSC): Comparison of the Collocation and Boundary Integral Methods applied to Two-Dimensional Crack Problems. Presented at the 19th National Symposium on Fracture Mechanics, June 30-July 2, 1986, San Antonio, Texas.

Results are given of an analysis of the relative strengths and weaknesses of the collocation and the boundary integral (BIE) methods when used in the determination of stress intensity factors for two-dimensional crack geometries. Single and multiple crack geometries are considered in both symmetric and unsymmetric configurations with trac-

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tions applied on the boundaries of the domain as well as on the crack surfaces.

15. Ting, P. C.; Rochelle, W. C. (Rockwell International); and Curry, Donald M. (JSC): Comparison of Viscous Shock Layer and Boundary Layer Reentry Heating Techniques for Orbiter Nose Cap. Presented at the AIAA /ASME 4th Thermophysics and Heat Transfer Conference, June 2-4, 1986, Boston, Massachusetts. AIAA Paper No. 86-1350.

Previous studies for predicting aeroheating to the Orbiter nose cap have used wind tunnel data, simplified heating correlations, and boundary layer solutions. This paper presents a comparison of viscous shock layer and boundary layer solutions at high altitudes including the effects of nonequilibrium chemistry and variable wall catalyticity. The Virginia Polytechnic Institute (VPI) shock layer program, a chemically reacting boundary layer program (BLIMPK) and the BLIMPK viscous shock layer option have been used to assess the Orbiter nose cap heating and flow field at high altitudes. Available Orbiter flight data will be used to compare with the predictions. The results of these studies indicate higher heating associated with the viscous shock layer solutions at altitudes greater than 200Kft. The two shock layer programs result in comparable heating rates for high wall catalyticity.

16. Ting, P. C.; Rochelle, W. C. (Rockwell International); and Curry, Donald M. (JSC): Aerodynamic Heating Environment on Orbiter Nose Cap with Dissimilar Surface Materials. Presented at the Association of American-Chinese Professionals 8th Annual Science and Engineering Technical Symposium, May 24-25, 1986.

This paper presents results of a study to evaluate the aero-dynamic heating environment around the Space Shuttle Orbiter nose cap in the region of the Shuttle entry air data system (SEADS) pressure ports during Orbiter entry and to determine the effect of surface catalycity on the columbium ports and on the reinforced carbon-carbon (RCC) thermal protection system material. The method of analysis was based on the kinetic version of the boundary layer integral matrix procedure (BLIMPK) Program. This paper presents results using this method with both the STS-9 best estimate trajectory (BET) and the design (14414. 1C) trajectory. The viscous flow field around the nose cap including atom mole fractions and heating distributions is discussed. Results were used in flight and arc-jet test thermal math models.

17. Visentine, James T.; and Leger, Lubert J.: Material Interactions With The Low Earth Orbital Environment.: Accurate Reaction Rate Measurements. Presented at the NASA Workshop on Atomic Oxygen Effects, November 10-11, 1986, Pasadena, California.

A flight experiment has been proposed for the Space Shuttle which utilizes an ion-neutral mass spectrometer to obtain in-situ ambient density measurements and identify reaction products from modeled polymers exposed to the atomic oxygen environment. An overview of this experiment is presented and the method of calibrating the flight mass spectrometer in a neutral beam facility prior to its use on the Space Shuttle is established.

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Flight Projects Engineering Office

1. Jenkins, Lyle M.: Teleoperators for Space Applications. <u>In Proceedings of the Workshop on Automation and Robotics for Military Applications,</u> October 22, 1986, Huntsville, Alabama.

   The current NASA activities in telerobotics, which is a combination of teleoperation and robotics, consist of studies, technology development, and the initiation of the flight telerobotic servicer for the Space Station. The basic concept of a space telerobot consists of two dextrous manipulator arms controlled from a remote station. This fundamental concept, as defined in studies of the telerobotic work system (TWS), has been expanded and evolved from the proposed initial application on the Space Shuttle for satellite servicing to a variety of functions on the Space Station. The development of a TWS represents a valuable resource for remote performance of a variety of tasks in the unstructured and hazardous environment of space. The concept of TWS provides a focus for robotic technology development beyond the realm of conventional industrial robotics with spinoff to military, firefighting, construction, and aid to the handicapped applications.

2. Jenkins, Lyle M.: Telerobotic Work System. Presented at the Human Factors Technology Symposium, June 16, 1986, Amalfi, Italy.

   The telerobotic work system (TWS) is a concept for performing tasks in space remotely from the operator. The approach combines functional capability of the flight crew controlling a pair of dextrous manipulator arms in a teleoperation mode with the system architecture for robotic modes of control. Rigors of space operations demand that autonomous activities be transparent to the human controllers. The inaccessibility of the work site makes alternative techniques of task completion important to success of a mission. The design approach for the TWS combines these elements in a system that increases the crew productivity as well as providing backup techniques to maximize probability of mission success. Productivity of the crew can be enhanced by remote operations with the TWS controlled from a shirt sleeve environment. Task compatibility with EVA capabilities should be retained to back up the TWS. The design of the control station for TWS operation will be influenced by the effects of zero G on the operator. Ground based teleoperation has demonstrated the advantages of force feedback in doing dextrous tasks. Restraints become critical in reacting the feedback forces. Other zero G effects may change the perception of displays. Manipulative task performance will be affected by response of the work pieces that will not have gravity to orient and retain them. Understanding the interaction of the mechanisms, control systems, and sensory perceptions of the task without gravity and atmosphere will be the thrust of the flight test program.

3. Jenkins, Lyle M.: Telerobotic Work System Definition Study. Presented at the AAS Annual Rocky Mountain Guidance and Control Conference, February 1-5, 1986, Keystone, Colorado.

   Requirements to service and repair satellites from the Space Shuttle and to construct the Space Station have created the need for supplements and alternatives to extravehicular activity (EVA) by space

crews. The application of automation and robotics in time critical
and hazardous operations is an important alternative capability for
Space Transportation System operations. The basic concept of a tele-
robotic work system (TWS) consists of two dextrous manipulator arms
controlled from a remote station. An increase in productivity can be
achieved by an evolution from teleoperation to telepresence to super-
visory control to a supervised adaptive robotic system. The TWS con-
cept is described as well as the system requirements, system architec-
ture, and development approach. The anticipated result is a system
that will have application on the Space Station, but will have been
developed and demonstrated on the Space Shuttle.

4. Jenkins, Lyle M.: Telerobotic Work System - Space Robotics Application.
   Presented at the 1986 IEEE International Conference on Robotics and
   Automation, April 7-10, 1986, San Francisco, California.
   The need to increase astronaut productivity for assembly, servicing,
   and maintenance missions has led to the definition of a concept for
   remote operations called the telerobotic work system (TWS). Dextrous
   manipulator arms are controlled from the Space Shuttle Orbiter cabin
   or a Space Station module. Concepts for the TWS have been developed
   by the Lyndon B. Johnson Space Center through contracts with the Grum-
   man Aerospace Corporation and Martin Marietta Aerospace. An evolu-
   tionary development of the system is proposed as a means of incorpor-
   ating technology advances. Early flight testing is needed to address
   the uncertainties of robotic manipulation in space. Space robotics
   can be expected to spin off technology to terrestrial robots, particu-
   larly in hazardous and unstructured applications.

5. Michel, Edward L.; and Huffstetler, William J.: Economy of Middeck
   Payloads. Presented at the 23rd Space Congress, April 22-25, 1986,
   Cocoa Beach, Florida.
   Whether adding microgravity to an experiment as a key ingredient or
   as an "X" factor, investigators need to minimize cost and risk while
   assuring adequate control and data. The crew quarters of the Space
   Shuttle Orbiter, called the middeck, offers the optimum environment
   for this type of activity. The experiment packages can be controlled
   by the investigator until shortly before launch, and can be retrieved
   shortly after landing. Utilities are readily available. Human inter-
   action and observation by astronauts and crewmembers is also possible.
   NASA is optimizing this resource with its new middeck accommodations
   racks (MAR's), which can displace the original galley normally carried
   on Spacelab module flights.

Space Station Engineering Office

1. Whitehurst, Troy N., Jr. (Boeing Aerospace Company): Space Shuttle Orbiter Ejection Seat Survey. Presented at the SAFE Association Annual Symposium, December 11-13, 1986, San Antonio, Texas.

   The Presidential Commission which investigated the Challenger accident recommended that NASA "make all efforts to provide a crew escape system for use during gliding flight." In response to that recommendation, government and industry studies were conducted of emergency ground egress, manual and powered extraction bail-out, powered flight mission aborts, water landing, and various seat and capsule ejection systems. This paper summarizes the survey of ejection seats which was done in support of the Ejection Escape Study Team. This survey determined which currently available seats can be incorporated into the Shuttle Orbiter and compared their performance capabilities with the Orbiter flight envelope. The systems, their differences, and the attributes which are significant to the Orbiter application are described. The conclusions of the survey were that the three seats in production meet essentially the same significant performance requirements, that all would require modifications for high altitude escape, and that DoD and industry specialists are available to provide the help needed to tailor the seats for Orbiter installation.

MISSION SUPPORT DIRECTORATE

1. Bordelon, James (Computer Science Corporation); and Voigt, Robert T.
   (JSC): NOMAD2 Application Performance Considerations. Presented at
   the NOMAD User's Conference, September 1986, Orlando, Florida.
   Factors to be considered in developing or performance tuning any
   NOMAD2 application system are discussed and summarized. A recommended
   approach to performance tuning a NOMAD2 system already in production
   is given. Examples of performance improvements achieved on an actual
   production system are included to illustrate the effectiveness of the
   techniques presented.

2. Graves, Larry; and Eisenhart, Wilmot L. (Link Flight Simulation Divi-
   sion): Systems Computational Considerations for Large Scale Man-In-
   The-Loop-Simulations. Published in _Proceedings of the 2nd European
   Simulation Congress_, September 1986, Antwerp, Belgium.
   With the advent of complex and highly sophisticated space systems, a
   need exists for large institutional simulations having built-in integ-
   rity for growth and modification throughout the life cycle of the sim-
   ulation. This integrity is imperative in order to stay abreast of
   real-world software and hardware modifications or additions, and to
   avoid the high costs of rehosting for each addition to the simulation.
   This paper addresses those large real time man-in-the-loop simulations
   with associated problems and suggested solutions and related trade-off
   analysis. Discussions will include capacity, expansion, synchroniza-
   tion, interfaces, operability, development reliability and cost as
   well as training requirements.

3. McCormick, Bernell R. (McDonnell Douglas Astronautics Company): Colli-
   sion Probabilities in Geosynchronous Orbit and Techniques to Control
   the Environment. Presented at COSPAR XXVI, June 30 - July 12, 1986,
   Toulouse, France.
   The collision probability of satellites in geosynchronous orbit is
   discussed and proposed techniques for controlling the geosynchronous
   environment are summarized. A new technique for predicting the expec-
   ted time between collisions is introduced and its results compared to
   those of previously used techniques. Its unique feature is the use of
   deterministic methods to model the motion of satellites and statisti-
   cal techniques to estimate collision probability, allowing realistic
   distributions of active and expired satellites to be used in the pre-
   diction process. Options for dealing with expired geosynchronous sat-
   ellites and an overview of a detailed analysis of options for removing
   spent upper stages (PAM-D, IUS, etc.) are given.

4. McCormick, Bernell R.; and Compton, James W. (McDonnell Douglas Astro-
   nautics Company): Mars Sample Return Ascent Vehicle Conceptual Guid-
   ance Algorithm. Presented at the AIAA Guidance, Navigation, and Con-
   trol Conference, August 18-20, 1986, Williamsburg, Virginia. Pub-
   lished in _Proceedings_.
   A conceptual guidance algorithm has been developed for the boost
   phase of the Mars Ascent Vehicle (MAV) based on numeric prediction/
   correction techniques. A numeric algorithm was chosen for its ability

to model external forces such as aerodynamic drag. This algorithm has been tested under dispersed conditons and has been found fast enough and accurate anough to satisfy the projected Mars sample return ascent requirements.

5. McCormick, Bernell R.; Fardelos, Pete L.; and Bond, Victor R. (McDonnell Douglas Astronautics Company): A Semi-Analytic Technique for Predicting Orbit Lifetime of Geosynchronous Transfer Orbits. Presented at the AIAA/AAS Astrodynamics Conference, August 18-20, 1986, Williamsburg, Virginia. Published in Proceedings.

This paper presents a semi-analytic technique for predicting orbit lifetime of geosynchronous transfer orbits. A previous study numerically predicted orbit characteristics that minimize orbit lifetime; however, no geometric explanation for these results was presented. The purpose of this paper is to offer a geometric explanation for these results by examining the important perturbations affecting orbit lifetime separately and superimposing these results.

6. Overman, E. Sam (University of Colorado at Denver); Simanton, Donald F. (JSC): Iron Triangles and Issue Networks of Information Policy. Public Administration Review, Vol. 46, Special Issue, pp. 584-589, November 1986.

Organizational decisions regarding computer technology and informatin policy can be seen as the outcome of either "iron triangles" or "issue networks." These constructs, borrowed from the federal policy-making literature, are easily interpreted in the context of automated data processing. Iron triangles are the traditonal trinity of users, managers and designers. Issue networks are looser and broader coalitions of many computer literate participants. At NASA's Johnson Space Center (JSC) issue networks provide the driving force in determining the way systems are designed and technologies chosen. The major information technology issues facing JSC were found to be the building of stronger communications networks, the need for greater commonality of systems and languages, improved planning, and prototyping as a system development method. Around these issues, broad networks of professionals, both inside and outside JSC, have coalesced to determine information policy and management within the organization.

SPACE STATION PROJECTS OFFICE

1. Wensley, David C. (McDonnell Douglas Astronautics Company): Interior
   Design of the U. S. Space Station Habitation Modules. Presented at
   the 37th International Astronautical Federation Congress, October
   4-11, 1986, Innsbruck, Austria.
   This paper describes design concepts for the habitation modules of
   the U.S. Space Station. A flexible interior architecture features
   modularized equipment compartments that permit access for maintenance
   and in-orbit reconfiguration as functional requirements change. The
   overall interior arrangement is presented with emphasis on crew quar-
   ters, operations and maintenance work stations, galley provisions,
   health maintenance facilities, and subsystem equipment compartments.
   Electrical and fluid utilities are shown. Design features to enhance
   crew comfort and safety are described as well as functional and design
   relationships with the European and Japanese modules and the U.S. lab-
   oratories.

SAFETY, RELIABILITY, AND QUALITYASSURANCE
DIRECTORATE

1. Clem, Daniel L.: Safety Considerations for Space Robots. Presented at Robexs '86, June 5-6, 1986, Houston, Texas.

    Robotics is one of the innovative approaches being considered to improve productivity and safety in future in future space systems such as NASA's Space Station. Robots can perform hazardous and repetitive tasks and free humans for safer and more productive activities. However, robots may also pose hazards. One obvious hazard is collisions with humans or equipment as a result of loss of control over the robot. Collision avoidance will become more difficult with the advent of autonomous/intelligent robots. NASA systems safety personnel are interested in utilizing robots to improve the safety of space operations and ensuring that safety is inherent in robot design. This paper explores some of the robotic safety enhancements, notes some of the safety concerns, and suggests ways to overcome these concerns. We explore these topics by focusing on industrial robots, the Space Shuttle RMS, existing space hardware requirements, and future robot concepts.

2. Cole, Matthew B.: Space Station Internal Environmental and Safety Concerns. Presented at the Spacecraft Fire Safety Workshop, August 20-21, 1986, Cleveland, Ohio.

    Space stations of the future will have many areas of concern involving safety in the internal environment. The research-oriented nature of Space Station operations will require that safety be of paramount importance to ensure crew survival and mission continuity. Fire is perhaps one of the more credible threats to the internal environment. The behavior of fire in the microgravity of space has not been extensively studied in the brief history of manned space flight. The inability of the crew to evacuate the fire area for extended periods of time and the space environment place constraints on the fire detection and suppression methods designed for use on a Space Station. Crew training to react to the fire threat and take the best course of action will be vital to crew safety.

SPACE STATION PROGRAM OFFICE

1. Craig, Mark K.: Definition Status of the U.S. Space Station System. Presented at the 38th International Astronautical Congress, October 4-11, 1986, Innsbruck, Austria.
   The U.S. Space Station program has completed definition activities and is now involved in Phase B preliminary design of the Station elements and systems. This effort will lay the ground work for the production Phase C/D activities which are to begin in 1987. The Space Station is being built to accommodate selective and adaptive phasing of capabilities. This is accomplished inherently in that elements of the Station such as modules and truss structure are natural replicate units. Innovative approaches to the design of Station systems are being emphasized with respect to three principal considerations: productivity, cost, and safety.

2. Egan, Gerald R.: Maintainability Planning for the Space Station. Presented at the AIAA Conference, April 2-4, 1986, Las Vegas, Nevada.
   Maintainability is being implemented during the Phase B (Definition and Preliminary Design) portion of the program by Space Station Program Office (Level B) and Project Office (Level C) personnel. A Maintainability Guidelines Document has been written and distributed to all four Phase B work-package centers. Trade studies are being performed to determine the most economical balance between initial cost (reliability) and life-cycle-cost (crew-time and replacement hardware cost). A working group which is comprised of Level B and Level C maintainability personnel will synthesize and evaluate the results of these trade studies, and from this data will generate a Maintainability Plan and Maintainability Requirements which will become a part of the Space Station design-and-build contract (Phase C/D).

3. Holt, Alan C.: Electromagnetic Braking for an Unmanned Mars Logistics Lander. Presented at the AIAA/ASME/SAE/ASEE Joint Propulsion Conference, June 16-18, 1986, Huntsville, Alabama.
   Several electromagnetic techniques should be extensively investigated as potential candidates for Mars lander propulsion system augmentation. For electromagnetic braking, pulsed microwave fields can be used to generate an enhanced plasma sheath which is acted upon by spacecraft-generated pulsed magnetic fields. This "plasmadynamic torquing" technique could be used to slow and turn the spacecraft. By generating microwave fields and plasma sheaths with specific geometries, asymmetric effects might be achieved which could be used for translation or force vectoring augmentation. This technique could increase landing approach flexibility by increasing surveillance and horizontal range capability.

4. Holt Alan C.: Hydromagnetics and Future Propulsion Systems. Presented at the St. Louis AIAA Technical Committee January 31, 1986, St. Louis, Missouri.

5. Holt, Alan C.: Mobile Robots and Artificial Intelligence for Large Payload Assembly and Maintenance. Presented at Robex 86 June 4-6, 1986,

Houston, Texas.

Several large payloads (dimensions greater than 10 meters) have been defined for potential assembly and installation on the initial operating capability (IOC) Space Station. These potential activities mean that the development of autonomous robotics and artificial intelligence systems must be paced, as a minimum, to match the required increase in large space structures assembly capability. Robots which are capable of flying aroung the Station and maintaining a certain position and attitude will be required. Propulsion capabilities (range and attitude hold duration) exceeding that of the manned maneuvering unit will be needed. The robots should also be able to grasp a structure and use two free arms to manipulate a structural element or perform another task. Extensive autonomous capabilities with embedded task learning techniques should be coupled with an advanced telerobotic mode which can be used to teach the robot a new task or to perform a time critical, contingency operation.

6. Nolan, Mark B.; and Stone, Dennis A.: Advanced Technology for the Space Station. Presented at EASCON 86, September 9, 1986, Washington, D.C.

This paper discusses the goals and objectives of the Space Station Advanced Development Program; the organization and approach used to implement the program; the technologies included within the program; the actions taken and planned to facilitate the transfer of the Advanced Development results and products into the mainstream of the Space Station design; and the planning for the continuation of the technology program to support the evolution and growth of the Space Station Program elements.

7. Rice, Robert R.: Space Station Power System Selection. Presented at the 21st Intersociety Energy Conversion Engineering Conference, August 25-29, 1986, San Diego, California. Published in Proceedings.

The current status of the power system selection is presented along with an evaluation of the process and system. The impacts on the station will be evaluated and described.

8. Rice, William E.: International Participation in Space Station. Presented at EASCON 86, September 9, 1986, Washington, D.C. Published in Proceedings.

A key aspect of the U.S. Space Station Program is the potential for significant participation and investment by other nations as partners to the U.S. in the design, development, and operation of NASA's next major goal, a permanently manned space station. Studies are underway in Canada, Europe, and Japan to examine and refine the basic characteristics of the candidate hardware elements proposed for complementary development by our international partners. This paper examines the fundamental concepts of the proposed partnership, the various hardware elements under consideration for development in Canada, Europe, and Japan, and the current activities aimed at reaching agreement so that the partnership can begin its development efforts towards achieving this ambitious cooperative space endeavor.

9. Weary, Dwayne P.: Solar Power for NASA's Space Station. Presented at the 13th Energy Technology Conference and Exposition, March 17-19,

1986, Washington, D.C.

Two basic approaches were considered to generate and store electricity on the Space Station. The first was the more traditional photovoltaics approach using solar cells to generate the electricity and electrochemical devices, either batteries or regenerative fuel cells, to store the power. The second approach examined was of use heat engines to convert solar energy into electricity (solar dynamics). This approach uses concentrated solar energy to heat a working fluid which in turn drives a turbine operating in either a closed Brayton or Rankine cycle. Energy is stored as heat using the large latent heat of fusion of metallic salts. Approaches considered for the primary power distribution system included high voltage DC and high voltage AC at a frequency of either 400HZ or 20KHZ.

WHITE SANDS TEST FACILITY

1. Benz, Frank J. (JSC); and Pedley, Michael D. (Lockheed Engineering and Management Services Company): A Comparison of the Explosion Hazards of Hydrazine and Methylhydrazine in Aerospace Environments. Presented at the 1986 JANNAF Propulsion Meeting, August 26-28, 1986, New Orleans, Louisiana.

    A comparison of the explosion hazards of hydrazine and methylhydrazine (also known as monomethylhydrazine or MMH) fuels in aerospace environments is presented. A section on hazards resulting from incompatibility covers the effect of materials on the fuels as well as the effect of the fuels on materials. Thermal hazards resulting from runaway reactions are also discussed. A section on hazards resulting from ignition covers flammability limits, ignition energies, spontaneous ignition, deflagration, detonation, and deflagration to detonation transition. A section on unusual hazards resulting from the aerospace environment describes the effects of changing altitude on flammability of the fuel, sublimation and freezing at high altitudes, and ignition resulting from rapid pressurization of the liquid fuels.

2. Benz, Frank J. (JSC); and Zhu, S. (Lockheed Engineering and Management Services Company): Ignition and Combustion of Metals in Oxygen: Fire Safety Considerations. Presented at the Spacecraft Fire Safety Workshop, August 20-21, 1986, Cleveland, Ohio.

    In oxygen, metals can ignite and undergo rapid combustion, thereby making metals fires difficult to detect and extinguish. This paper provides a review of the ignition and combustion properties of metals and speculation on how these properties might change in zero-gravity environments. Review of the ignition and combustion properties of metals indicates that they are controlled by different processes. Ignition of metals is dependent on the rate of the heat generated by oxidation and on the rate of heat lost prior to ignition. Oxidation prior to ignition is strongly dependent on the state and properties of the oxide coatings that form and adhere to the metal surfaces. Combustion of metals is dependent on whether the metal burns as a vapor or as a liquid. The hot molten mass produced during combustion has a large effect on the burn propagation rate of metals, which, in turn, has a large effect on the flammability properties of metals. In zero-gravity environments, it is believed that the ignition properties of metals will not change significantly from those observed in one-gravity environments; however, the combustion and flammability properties may change as the force of gravity is eliminated.

3. Bishop, C. V. (Lockheed Engineering and Management Services Company); Benz, Frank J. (JSC); and Ullian, L. J. (U.S. Air Force): Mixing of Cryogenic Fluids and Predicted Detonation Properties for MultiPhase Liquid Oxygen and Liquid Hydrogen. Presented at the 1986 JANNAF Propulsion Meeting, August 26-28, 1986, New Orleans, Louisiana.

    The mixing and explosion of LOX and LH_2 is a concern for National STS Program operations. To understand this problem, cryogenic mixing is experimentally studied by pouring 1,2,2-trichloro-2,1,1-trifluoroethane (Freon 113) into LN_2, LN_2 into LH_2, and LH_2 onto LN_2 in a 1m x

15cm cylindrical glass vessel. Data from these experiments is compared with previous studies and a hypothesis advanced that LOX/LH$_2$ mixing will result in a complex, heterogenous, multiphase aggregation including LOX, SOX, LH$_2$, and VH$_2$. Calculations on the internal (Chapman Jouguet) detonation properties for each combination of phases and for an aggregate are presented. Visual and x-ray observations of the process and mass measurements are reported. Freon 113 in LN$_2$ forms a buoyant jet with nucleate boiling. LH$_2$ onto LN$_2$ does not mix, but rather "floats" atop LN$_2$. LN$_2$ poured into LH$_2$ forms a turbulent jet with nucleate boiling. The jet front obtains a constant velocity after impact. Calculated for LN$_2$ into LH$_2$ is a Reynolds number of 1,800,000; a Weber number of 7.2; heat transfer coefficients varying from 5 to 34 kW/m^2; bubble diameters of 3.0 to 5.0 mm, containing nitrogen nuclei of less than 1mm diameters; concentrations of LN$_2$ of 0.15 molar, with mixture densities between 5.3 and 74.2 kg/m^3, corresponding to mole fractions between 0.004 and 0.23 in the jet and 0.86 in the bubbles. Physical explosions, when LN$_2$ was poured into LH$_2$, did not occur.

4. Kays, Randy; and Mahone, William (Lockheed Engineering and Management Services Company): Prototype Test System to Measure the Mass Loss of Condensable Outgassed Products in an Isothermal Vacuum. Presented at the AIAA/ASME 4th Joint Thermophysics and Heat Transfer Conference, June 2-4, 1986, Boston, Massachusetts.

Investigators at the NASA White Sands Test Facility (WSTF) are currently studying ways to determine the rate at which condensable products outgas from configured items in space-simulation chambers. The WSTF throughput test method can be used to measure this rate when the partial pressure of the condensable products is determined from quartz crystal microbalance (QCM) data. To test this concept, a prototype test system is being constructed that will consist of a high-vacuum chamber with an isothermal vessel and two or more QCMs. Preliminary tests completed at WSTF support the validity of this unique approach.

5. Mahone, William; and Kays, Randy (Lockheed Engineering and Management Services Company): The Behavior of Outgassed Materials in Thermal Vacuums. Presented at the Space Simulation Conference, November 3-6, 1986, Baltimore, Maryland.

Scientists at the NASA White Sands Test Facility (WSTF) are investigating the relationship between pressure and condensation rates of outgassed materials. The validity of the WSTF throughput test method was previously tested at WSTF using palmitic acid. Data from these tests were compared to data from other preliminary tests using adipic and behinic acid. The comparison indicated that surface forces between outgassed molecules and the condensing surfaces can cause the condensaton flux to be different from the incident flux. They can also cause the evaporative flux, away from a surface, to be different from the expected value. These discrepancies are discussed in terms of both potential and dynamic interactions of outgassed molecules with surfaces.

6. Stradling, Jack: Compatibility of Materials With Oxygen. Presented at the Compressed Gas Association Safety and Technical Symposium, October 7-8, 1986, Cherry Hill, New Jersey.

The oxygen materials test experience background of the White Sands

Test Facility is discussed. The basic elements of combustion are reviewed (fire triangle, etc.). The process of selecting both metals and nonmetals for oxygen service is investigated. The importance of designing for contamination control as well as the need for institution and maintenance of rigorous cleaning programs is emphasized. Many pictorial examples of material, component, and system failures are provided.

7. Stoltzfus, Joel (Lockheed Engineering and Management Services Company): Testing Metals and Alloys for Use in Oxygen Systems. Lockheed Horizons, Vol. 22, pp. 40-47, December 1986.

Advancing technology is creating a demand for higher oxygen-use pressures and temperatures, which increase the risk of and damage caused by fire. Engineers who design oxygen systems must carefully test and select the metals and alloys to be used in those systems. At the NASA White Sands Test Facility, Lockheed Engineering and Management Services Company is working with NASA to develop four test systems that can be used to evaluate metals and alloys for use in oxygen systems. The frictional heating and the particle impact test systems simulate ignition sources that have caused fires in gaseous oxygen systems. The promoted ignition and flame propagation test systems simulate conditions that occur in oxygen systems once a fire has been started. Results from test programs using these systems have been used to improve the design of an oxygen flow control valve for the Space Shuttle and to aid in the design of engines for the orbital transfer vehicle. The four test systems are also being used to contribute significantly to scientific research. As a more complete understanding of the ignition and combustion is obtained, advances in the state of the art of metals and alloys used in oxygen systems will be made.

SPACE AND LIFE SCIENCES DIRECTORATE

Medical Sciences Division

1. Bowie, W. H. (Technology, Incorporated): Space Bioreactor Development. Presented at the E. L. Miller Lecture Series, Fall 1986, College Station, Texas.

   The Space Bioreactor Program was divided into three phases. Phase I was devoted to concept demonstration and utilized Mouse lymphocytes (strain L1210). Phase II was to be a transition and research phase in which an appropriate cell type for future work would be selected. It also was intended to be an ongoing effort that would continually feed information into a flight development program (Phase III). The targeted cell type for post conceptual prototype and flight operations was an HEK strain which required substrate attachment for growth. Such cells are fragile and require sophisticated engineering and control techniques to provide an adequate environment for growth. The current bioreactor designs, known as laboratory test units (LTU's) incorporate some of the anticipated levels of sophistication but are still under development and are expected to become more autonomous with time. Several cell runs utilizing HEK cells on microcarriers have been completed in the LTU's. The results to date have been employed primarily to define improvements needed in the laboratory units.

2. Broadwell, D. K. (University of Texas School of Public Health); and Logan, James S. (JSC): A Total Parenteral Nutrition System For Emergency Use Aboard the Space Station Health Maintenance Facility. Presented at the Aerospace Medical Association Annual Scientific Meeting, April 20-24, 1986, Nashville, Tennessee.

   In addition to its preventive duties, the SS Health Maintenance Facility (HMF) must prevent unnecessary rescues and improve survivability of the injured or seriously ill awaiting rescue, requiring a system of intravenous nutritional support for periods up to 28 days in a microgravity environment and meet projected metabolic needs of an ill crewmember. The technical status of aseptic fluid transfer systems, available energy substrates, and delivery hardware was surveyed. A prototype total parenteral nutrition (TPN) system was developed that can accommodate either central or peripheral intravenous access methods. This is accomplished by using a lyophilized glucose-amino acid mixture in a 3-4 liter capacity bag, reconstituted by adding varying amounts of sterile USP water generated onboard. This delivers a minimum of 30% over estimated basal metabolic requirements and utilizes a lipid emulsion for a portion of the delivered calories. A rehydratable TPN system for use in the Space Station HMF is feasible and could be implemented without major advances in TPN techniques.

3. Bungo, Michael W.; and Charles, John B.: The Central Cardiac Hemodynamics of Acute Exposure to Microgravity. Presented at the International Union of Physiologic Societies Meeting, November 10, 1986, Tokyo, Japan.

   Echocardiography obtained before, after, and during exposure to

microgravity and noninvasive estimation of central venous pressure (CVP) during weightlessness have provided quantitative insights into the human cardiovascular adaptation to microgravity. Right ventricular dimension was found to be 35% decreased throughout the period of weightlessness and returned to baseline after flight. Left ventricular end-diastolic volume index (LVDVI) was 20% increased during weightlessness. After an 85% rise in cardiac index the first day, values returned to preflight levels for the duration of the mission. CVP estimated from the jugular vein stop flow pressure decreased progressively from preflight values for the first 3 days of microgravity and then reached a plateau. Recovery from 7 days in space appeared to require a week of re-exposure to Earth's gravity.

4. Calkins, Dick S. (Technology, Incorporated); and Reschke, Millard F. (JSC): Empirically Determined Reliability of Scores for Several Motion Sickness Susceptibility Tests. Presented at the Space Adaptation/7th International Man in Space Symposium, February 10-13, 1986, Houston, Texas.

At the NASA Space Biomedical Research Institute's neurophysiology Laboratory, the motion sickness susceptibility tests used are the staircase velocity motion test (SVMT), coriolis sickness susceptibility index (CSSI), off vertical rotation (OVR), sudden stop test (SST), and the static chair during parabolic flight test. Recently acquired computing capability and accumulation of data from sufficient numbers of subjects has facilitated the empirical determination of values of reliability for some of these tests, presented here with a discussion of the implication of these values for space motion sickness research. Sufficient data exist to enable calculation of reliability values for the CSSI, SVMT and the static chair test during parabolic flight. Reliability values reported are of the test-retest type and were obtained by correlating scores for the same subjects in a test under equivalent conditions on two or more occasions.

5. Charles, John B.; and Bungo, Michael W.: Cardiovascular Research in Space: Considerations for the Design of the Human Research Facility of the United States Station. *Aviation, Space, and Environmental Medicine*, Vol. 57, pp. 1000-1005, October 1986.

This brief review summarizes our knowledge of space physiology as it relates to the cardiovascular system. Only actual flight information is utilized; no attempt is made to include the wealth of ground based simulation data nor are areas remote to the cardiac system discussed. Gaps in current understanding are highlighted in a manner of suggested plans for future spaceflight investigations.

6. Cintron, Nitza M.: Medicine and Drug Therapy in Space. Presented at the American Association for the Advancement of Science Annual Meeting, May 25-30, 1986, Philadelphia, Pennsylvania.

Physiological and biochemical changes that are documented to occur during space flight may influence the pharmacodynamics and therapeutics of drugs administered to crew members. Due to the lack of technical feasibility coupled with operational constraints of such studies during space flight, clinical drug monitoring in space remains an uninvestigated aspect of space medicine. Therefore, developing and testing simple, noninvasive sample collection methods and establishing

clinical pharmacokinetic profiles of some important drugs used during flight are important for successful space medical operations of the future. Efforts are focused on characterizing inflight pharmacokinetics of drugs such as acetaminophen and scopolamine whose kinetic profiles on the ground have been established using salivary concentrations. Preliminary results suggest that significant changes in the drug dynamics occur during flight.

7. Cohly, Hari H. P.; van Oss, Carel J.; Albini, Boris (SUNY); and Morrison, Dennis R. (JSC): Mechanism of Electrophoretic Cell Separation Using Double Antibody Procedure. Presented at the American Chemical Society 1986 Annual Meeting, November 19-21, 1986, Houston, Texas.

Ascending preparative electrophoresis in conjunction with double antibody procedure (DAB) has been shown to be useful in purifying mouse intestinal intraepithelial lymphocytes and T splenocytes. To elucidate the mechanism of DAB on electrophoretic mobility, microelectrophoresis was performed. The mobility of human mononuclear cells and epithelial cells was reduced by 36-38% and mobility of human D erythrocytes was reduced by 17%. When using cationized second antibody, mobility was reduced by 62-77%, while the use of cationized first antibody had no significant effect on the mobility. These results suggest that a second antibody is necessary to reach above the cell's glycocalyx. Futhermore, mobility of blood group A1 was reduced by 26% and blood group N was reduced by 31%. These results confirm that a second antibody is required when the antigen exists in the cell membrane while first antibody suffices to affect mobility when the antigen is in the glycocalyx.

8. Cross, John H.; Schwarz, R.; Bowie, W. H.; Lewis, Marian L.; Anderson, C. D. (Technology, Incorporated); and Morrison, Dennis R. (JSC): Development of a Space Bioreactor. Presented at the American Chemical Society 1986 Southwest Regional Meeting, November 19-21, 1986, Houston, Texas.

A bioreactor is being developed that will, in microgravity, sustain a mammalian cell culture, allow studies of novel culture methods, and produce a crude isolate of medically-important proteins. The cells are cultured on 180μm Sephadex beads suspended in a nutrient medium. On Earth, the stirring required to suspend the beads also damages the cells. In space, less stirring is required, because the beads are weightless. Also under investigation are novel techniques for oxygenation. For example, air bubbles can be kept in the medium until a specified fraction of the oxygen has been used. The bioreactor is being designed to provide cells for biological studies in microgravity or to produce a crude isolate of proteins secreted from cells. In a complete space bioprocess, this protein isolate would be fed to a purification step such as the Continuous Flow Electrophoresis System, which has proved efficient in microgravity. In addition to the design concepts, results from tests of a prototype space bioreactor will be presented.

9. Damron, Kevin; Lewis, Marian L. (Technology, Incorporated); Barlow, Grant H. (Michael Reese Research Foundation); Morrison, Dennis R. (JSC): Comparison of Fibrinolytic and Chromogenic Methods for the

Assay of Plasminogen Activators in Culture Medium From Kidney Cell Subpopulations. Presented at the 8th International Congress on Fibrinolysis, August 24-29, 1986, Vienna, Austria.

Plasminogen activator (PA) in serum free conditioned medium (CM) from electrophoretically separated subpopulations of human kidney cells was tested for activity by fibrin plate lysis (FPL), amidolytic assays (S-2444), tissue PA (t-PA) ELISA, and a micro-clot lysis (MCLA). For comparison of PA production by ESS, we have shown that a battery of assays must be employed to define the several expressions of the activators. Some ESS tested by S2444 and MCLA produced similar PA activity, yet higher activity by FPL. S2444 and MCLA did not measure single chain urokinase like PA (scu-PA) which may have affected FPL. Scu-PA is measureable by preincubation of CM with plasmin and subsequent test by S-2444. FPL does not define contributions of scu-PA nor active t-PA and is less sensitive to plasmin inhibitor found in samples in which MCLA values were 2-4 times lower. MCLA measures active urokinase plus some of the scu-PA in samples.

10. Dardano, Joseph R. (Northrop Services); Johnson, Philip C.; and Leach, Carolyn S. (JSC): A Flow Cytometric Method for the Enumeration of Reticulocytes in Peripheral Blood. Presented at the 1986 Aerospace Medical Association Scientific Meeting, April 20-24, 1986, Nashville, Tennessee.

Standard clinical laboratory methods for the enumeration of reticulocytes in peripheral blood involve staining of blood smears with a supravital stain. Flow cytometry, coupled with Pyronin Y, an RNA specific fluorescent stain, allows rapid identification of subpopulations of reticulocytes in large numbers of cells. The stability of the stain and reproducibility of the procedure were tested in multiple subjects. The method offers an alternative to currently used manual reticulocyte counting techniques. Utilizaton of fixed cells provides a method whereby blood samples taken during space flight can be analyzed.

11. Galen, Theodore J. (Northrop Services): A Solid Sorbent Air Sampler for Use on the Space Shuttle. Presented at the Air Pollution Control Association Meeting, March 19, 1986, Chattanooga, Tennessee.

Onboard each Shuttle mission, there are one or more evacuated cylinders in which are collected instantaneous whole gas grab samples of the atmosphere. Multiple samples are collected at the beginning, middle, and end of the mission. Recently, a new and improved method of continously sampling the Orbiter atmosphere, called the solid sorbent air sampler, has been developed and flown. It is capable of compositing samples on a 24 hour basis for 8 days, requires no spacecraft utilities, and is of minimal size and weight. Both of the above sampling procedures result in samples which must be analyzed in the laboratory. A project has been initiated to develop an onboard inflight analyzer that is capable of both sampling and analyzing the atmosphere on a real time basis. A maximum of 96 compounds have been identified in the cylinder samples collected during the first 20 Shuttle missions. The solid sorbent air sampler has flown 3 times to date with over 45 trace level compounds detected. Toxicological assessment of the analytical data derived from the air samples collected during

Shuttle mission indicates that the limits of spacecraft maximum allow-
able concentrations for volatile compounds have not been exceeded.

12. Galen, Theodore J. (Northrop Services); and Pierson, Duane L. (JSC):
    Inflight Shuttle Atmospheric Samples Collected with the Solid Sorbent
    Air Sampler. Presented at the 1986 Aerospace Medical Association Sci-
    entific Meeting, April 20-24, 1986, Nashville, Tennessee.

    The solid sorbent air sampler was used to collect composited air
    samples from the Orbiter middeck atmosphere during the STS 51-B mis-
    sion. Atmospheric samples were continuously collected from the Or-
    biter forward middeck area by flowing air through the sampler at a
    rate of 2.9 liters per 24 hour period. The solid sorbent material,
    Tenax, was contained in eight glass lined stainless steel tubes within
    the sampler. An individual tube was assigned to each 24 hour collec-
    tion period. Following the mission, the solid sorbent air sampler was
    returned to the JSC Toxicology Laboratory for desorption and analysis
    by gas chromatography/mass spectrometry. A total of 47 different
    trace gas contaminants were found in one or more of the Tenax tubes of
    the sampler. All contaminants were well below their repective space-
    craft maximum allowable concentrations. A composite record of all
    volatiles that were present over each 24 hour sampling period was ob-
    tained. The method was sensitive enough to permit quantitative iden-
    tification of each contaminant.

13. Harm, Deborah L. (JSC); and Kotses, Harry (Ohio University): Cardio-
    Respiratory Responses to Time Pressure. Presented at the Society for
    Psychophysiological Research Meeting, October 1986, Montreal, Quebec.
    Published in Psychophysiology, Vol. 23, p. 439.

    The purpose of the present study was to examine changes in cardiac
    and respiratory activity in response to varying levels of time pres-
    sure (TP), and to examine the predictability of cardiac responses from
    changes in specific parameters of the breathing pattern by means of a
    version of the Stroop color-word conflict test. Results indicated
    that cardiac and respiratory activity were substantially affected by
    task performance. Heart rate (HR), heart rate variance (HRV), respira-
    tory rate (RR), inspiratory volume (IVL), inspiratory flow rate (IFR),
    expiratory time (ET), and expiratory flow rate (EFR) measures changed
    significantly from baseline to trial. Analyses of variance revealed a
    significant increase from baseline to trial in HR, RR, IFR and EFR,
    whereas HRV, IVL, and ET decreased significantly. Although these re-
    sponses did not differ for the two levels of time pressure, the magni-
    tude of responses from baseline to trial was generally greater (by ap-
    proximately 50%) in the high TP condition than the low TP condition.
    Inspiratory flow rate predicted HR, and ET predicted HRV. The data
    support the general contention that a number of specific components of
    the breathing pattern along with cardiac variables are substantially
    affected by task performance, and that certain respiratory parameters
    may be predictive of cardiac responses.

14. Horrigan, David J., Jr. (JSC); Stanford, J., Jr.; Edwards, B. F. (Tech-
    nology, Incorporated); and Waligora, James M. (JSC): EASE/ACCESS

EVA's: Biomedical Data. Presented at the Space Construction Conference, August 6-7, 1986, Hampton, Virginia.

The metabolic rates during the EASE/ACCESS EVA'S of flight STS 61-B are compared with the rates previously recorded during Apollo, Skylab, and Shuttle EVA's. These biomedical data are based on heart rates and oxygen utilization, as well as crew comments. Although metabolic rates can be estimated from heart rate data compared to that recorded during 1-g training, oxygen consumption is a better measurement of actual metabolic energy expended during EVA. Earlier Shuttle EVA's provided us with only one or two readings on the oxygen utilization, but starting with the 61-B mission we have the oxygen data which is time correlated with most of the individual tasks. The average metabolic rate in the Apollo EVA's was 235.1 Kcal/hr (940.4 BUT/hr) and Skylab EVA's averaged 238.4 Kcal/hr (953.6 BTU/hr). Shuttle EVA's show a significantly lower average metabolic rate - 199.38 Kcal/hr (797.52 BTU/hr). Averaging both crewmembers together for the EASE/ ACCESS EVA's gives us values of 231.5 Kcal/hr (926 BTU/hr) for the first EVA and 199.5 Kcal/hr (798 BTU/hr) for the second EVA.

15. Horrigan, David J., Jr.; Waligora, J. M. (JSC); Gilbert, J. H.; Conkin, J. (Technology, Inc.); and Stanford, J. (JSC): An Evaluation of a 10.2 PSI Space Cabin Pressure and a 6 PSI Suit for Prevention of Altitude Decompression Sickness. Presented at the Aerospace Medical Association Scientific Meeting, April 20-24, 1986, Nashville, Tennessee.

In planning for Space Station cabin and suit pressures, it is desirable to establish a procedure which will have a low probability of eliciting intravascular bubbles or symptoms of decompression sickness. The results reported here provide the basis for an evaluation of decompression approximately equivalent to a sea-level cabin and a 9.5 psi suit. Twenty nine human volunteer subjects, selected by age and body fat content similar to the astronaut population, breathed 100% O_2 for 2 hours before decompression in an altitude chamber to an atmosphere of 10.2 psi (28 % O_2, 72 % N_2). They remained at 10.2 psi, breathing that atmosphere for 24 hours, to assure complete equilibration to the lower nitrogen tension. Then a second decompression to 6 psi (60 % O_2, 40 % N_2) enabled them to perform a 6-hour exercise period at metabolic levels similar to those of actual extravehicular activities in space. Precordial doppler monitoring was done every 16 minutes. Of the 29 exposures, there were 3 instances of intravascular bubbles and 1 possible case of mild limb bends. No other symptoms were reported. Exposure to this 6 psi atmosphere with EVA-level of exercise after equilibration to the above described 10.2 psi atmosphere has a very low probability of eliciting intravascular bubbles or symptoms of decompression sickness in this population of subjects.

16. Hunter, Norwood R. (Northrop Services); Greenberg, S. Donald (Baylor College of Medicine); Taylor, Gerald R. (JSC); Swank, Paul R. (Technology, Incorporated); Trahan, Elizabeth B.; Montalvo, Jorge G.; Spjut, Harlan J.; and Estrada, Rolando (Baylor College of Medicine): A Comparison of Cell Atypia Profiles From Squamous and Nonsquamous Lung Cancers. Presented at the 5th International Conference on Automation of Diagnostic Cytology and Histology, May 30, 1986, Brussels, Belgium.

To investigate the possibility that the pattern of bronchial dyspla-

sia associated with different types of cancers might be similar, an Atypia Status Index (ASI) was determined for each of 200 randomly-selected atypical bronchial epithelial cells per subject. We have previously decribed our ASI as a value determined from the features of the digitized image of each atypical bronchial epithelial cell which represents the level of atypia in numerical terms. The distribution of ASI values for each sample of 200 atypical cells is called a Cell Atypia Profile (CAP). CAP's were obtained and compared for squamous and nonsquamous cancers of the lung. Preliminary results show that CAP's from nonsquamous cancers have distributions skewed toward the least atypical end of the ASI scale while CAP's from squamous cancers show distributions skewed toward the most atypical end of the ASI scale. This indicates that the histogenesis of nonsquamous cancers of the lung may be different from that of squamous cancer of the lung.

17. Johnson, Philip C.: Adaptation and Readaption Medical Concerns of a Mars Trip. Presented at the Aerospace Medical Association Scientific Meeting, April 20-24, 1986, Nashville, Tennessee.
    Using a Mars trip as a model, the following flight medicine considerations peculiar to a long duration space trip will be discussed: (1) long term health prediction techniques, (2) readaptation to gravity, (3) sensory defects of aging, (4) bone and muscle atrophy prevention, (5) EVA Cardiac electrical instability, (6) generalized atrophy of tissue cells, (7) malignant tumors, (8) infectious diseases, (9) space radiation effects on carcinogenesis, (10) delayed immunity impariment, (11) partial artificial gravity, and (12) solving the space adaptation syndrome.

18. Kohl, Randall Lee (Universities Space Research Association): Dexamethasone Mimicks the Antimotion Sickness Effects of Amphetamine and Scopolamine. Acta Astronautica, Vol. 13, No. 9, pp. 565-571, 1986.
    Based on preliminary suggestions that individual differences in susceptibility to stressful motion might be related to physiological differences in responses of the hypothalamic-pituitary-adrenal axis, we tested the efficacy of dexamethasone and metyrapone in subjects exposed to cross-coupled accelerative semicircular canal stimulation on a rotating chair. Subjects given 0.5 mg of dexamethasone every 6 h for 48 h could endure 80% more stressful motion (P=0.03) in a within-subjects design study, whereas no improvement followed treatment with 750 mg of metryapone every 4 h for 24 h. The efficacy of dexamethasone might be explained in terms of its neurochemical actions on several neurotransmitter systems which are also modulated by such classical antimotion sickness drugs as amphetamine and scopolamine. Because dexamethasone induces adaptive changes within the central nervous system it may prove superior to scopolamine and amphetamine, which posssess significant side effects, are short acting, and rapidly tolerated.

19. Kohl, Randall Lee (Universities Space Research Association): Effects of Parabolic Flight, Nausea, Emesis, and Metoclopramide on Serum Levels of ACTH and AVP in man. Presented at the 7th International Academy of Astronautics Man in Space Symposium, February 10-13, 1986, Houston, Texas.
    Metoclopramide (Reglan) was orally administered (10 or 20 mg) to 22

subjects, 75 minutes before stressful linear acceleration induced by parabolic flight maneuvers on a KC-135 aircraft. Serum levels of adrenocorticotropic hormone (ACTH) and arginine vasopressin (AVP) were not significantly altered by drug treatment alone, at either dose. Metoclopramide was ineffective in modulationg the incidence of emesis induced by parabolic flight as reported elsewhere. These findings are consistent with the suggestion of Rowe et al. (1979) that the presence of nausea is correlated with AVP release. Inhibition of AVP release mediated by the headward fluid shifts occurring during parabolic flight and during sustained microgravity might account for the present findings and the reports by astronauts of episodes of vomiting without emesis.

20. Kohl, Randall Lee (Universities Space Research Association): Failure of Metoclopramide (M) to Prevent Motion Sickness During Parabolic Flight (PF) or on the Rotating Chair. Aviation, Space, and Environmental Medicine, Vol. 57, No. 5, 1986.
    Metoclopramide (M) at doses of 10 to 20 mg was given 75 min prior to provocative PF and coriolis stimulation in the rotating chair. Subjects undergoing 40 PF maneuvers were taken to an endpoint of emesis; nausea II marked the point at which the rotating chair was stopped. A majority of subjects (63%) experience minimal symptoms during PF, however, those showing emetic responses do so reproducibly and despite the presence of M. Motion sickness may be overriding any therapeutic action of M on GI functioning or the chemotrigger zone.

21. Kohl, Randall Lee (Universities Space Research Association): A Pharmacological and Physiological Review of Space Motion Sickness. Presented at the Winter Conference on Brain Research, January 25 - February 1, 1986.
    Terrestrial motion sickness is prevented by sympathomimetic, anticholinergic, antihistaminergic, and glucocorticoid drugs, but not by specific peripherally acting antihistamines or agents facilitating gastric emptying. Although the etiology of terrestrial or space motion sickness remains unknown, several theories have been advanced to account for the therapeutic benefits of these drugs and suggest possible physiologic mechanisms in the malady. The poster presentation reviews the evidence for these mechanisms, presents data on the antimotion sickness efficacy of methamphetamine, methylphenidate, pemoline, phenmetrazine, phentermine, astemizole, dexamethasone, metyrapone, metoclopramide, and gives preliminary results on the efficacy of thyrotropic releasing hormone, scopolamine plus amphetamine, and doxepin. Discussion focuses on endocrine and autonomic manifestations of motion sickness, roles these responses play in either the etiology or resolution of the malady, and on the existence of specific biochemical profiles which may characterize an individual's susceptibility or adaptability.

22. Kohl, Randall Lee (Universities Space Research Association); and Calkins, Dick S. (Technology, Incorporated): Arousal and Stability: The Effects of Five New Sympathomimetic Drugs Suggest a New Principle for the Prevention of Space Motion Sickness. Aviation, Space, and Environmental Medicine, Vol. 57, No. 2, pp. 137-43, 1986.
    Sympathomimetic agents are frequent components in antimotion-sick-

ness drug combinations because of their usefulness in counteracting the sedation caused by stressful motion or resulting from the administration of other antimotion-sickness drugs. The noradrenergic neurochemistry of the brain's arousal-attentional systems prompted us to evaluate the efficacy of five new sympathomimetic drugs and to further define the role of arousal in susceptibility to motion. Subjects were orally administered methamphetamine (20 mg), phenmetrazine (25 mg), phentermine (37.5 mg), methylphenidate (20 mg), or pemoline (75 mg) 2 h prior to taking a Staircase Profile Test. All of the drugs increased resistance to stressful coriolis stimulation by 80-120%. Methylphenidate and pemoline showed fewer side effects. These findings, interpreted in conjunction with the documented inefficacy of most anticholinergic and antihistaminergic drugs tested to date, suggest that sympathomimetic drugs or a generalized state of arousal can inhibit the development of motion sickness.

23. Krebs, Jean M. (Technology, Incorporated); Schneider, V.; Cintron, Nitza, M. (JSC); LeBlanc, Adrian (Technology, Incorporated); Kuo, C. M. (Northrop Services); Johnson, Philip C.; and Leach, Carolyn (JSC): The Effect of Bed Rest and Fluoride Supplementation on Copper, Zinc and Alkaline Phosphatase Levels in Healthy Males. Federation of American Societies for Experimental Biology Annual Meeting, April 1986, St. Louis, Missouri.

We previously reported that bed rest decreased zinc (Zn) balance and increased serum Zn levels and that 10 mg fluoride (F)/d supplementation increased Zn balance in 9 healthy males. This study has been expanded to include fecal copper (Cu) excretion, serum Cu levels and alkaline phosphatase levels because these may be important to bone formation. Twelve healthy males (ages 19-44) remained on a metabolic research ward for 10 weeks. During weeks 1-5 subjects were ambulatory, and during weeks 6-10 subjects remained in continuous bed rest. Six subjects received 10 or 20 mg F/d during weeks 3-10. Weekly fecal composites were made, and biweekly fasting serum samples were taken. Dietary intakes of Cu and Zn were 1.45 and 10.36 mg/d, respectively. Alkaline phosphatase levels increased with F supplementation ($p < 0.05$). Fecal Cu excretion (0.97 ± 0.06 mg/d) and serum Cu concentrations (1.12 ± 0.10 mg/l) were not changed by bed rest or F supplementation, whereas the changes in Zn balance and serum Zn levels previously reported were confirmed. These results are compatible with increased bone resportion during bed rest and increased bone formation with F supplementation.

24. Kutyna, Frank A.: Space Motion Sickness: Status Report. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986 San Diego, California.

Space motion sickness is only one component of the larger multifactoral problem of space adaptation syndrome (SAS). The conditions of spaceflight and habitation in space consequent to Space Station tours and Mars voyages necessitates the understanding of SAS and the physiological mechanisms evoked by this response. Minimizing mal-adaptive physiological responses while enhancing those mechanisms which appropriately cope with the gravitoinertial conditions of spaceflight will require an intimate knowledge of the physiology of manned spaceflight and the adaptive process in order to best utilize, for the purpose of

minimizing space motion sickness, those homeostatic mechanisms inherent in the physiology of man.

25. LeBlanc, Adrian (Technology, Incorporated): In Vivo Nuclear Magnetic Resonance Imaging. NASA CR-179902, May 1986, 34 pp.

Magnetic resonance imaging is being used to investigate physiological changes induced by microgravity. Using human (bed rest) and animal (tail suspension) models simulating zero gravity, muscle atrophy was studied. Despite significant physiological changes in muscle mass, distribution of blood flow, and muscle water, no changes in muscle proton relaxation times were found at several different resonant frequencies (6, 10, 20, 200 MHz). These results suggest that observed changes in relaxation times as reported in pathological studies is likely due to the pathological changes and not the accompanying muscle atrophy.

26. Lewis, Marian L. (Technology, Incorporated): Growth of Attachment Dependent Human Kidney Cells in a Laboratory Model Space Bioreactor. Presented at the 1986 American Society for Cell Biology Meeting, December 7-11, 1986, Washington, D. C.

This report describes experience in maintaining human kidney cells attached to Cytodex 3 microcarrier beads in the ground based laboratory test unit (LTU) bioreactor. These normal diploid cells were initially grown to semi-confluence on beads in static petri plate cultures. Before incoulation into the LTU, growth medium was replaced with serum-free maintenance medium. Factors affecting cell survival including cell handling, seeding density, occult system toxicity and effect of deceased cell lysate were evaluated. The loss of cells within the first 12 hours appeared to be directly related to preloading cell handling procedures and to vessel spin rate. Assay for secreted urokinase and t-PA confirmed that production levels in the LTU were detectable by 24 hours. These ground based evaluations are preliminary to the cell biology flight experiments planned for the space model bioreactor.

27. Lewis, Marian L. (Technology, Incorporated); Barlow, Grant H. (Michael Reese Research Foundation); Damron, Kevin L. (Technology, Incorporated); and Morrison, Dennis R. (JSC): Activation of scu-PA In Human Kidney Cell Culture Medium: Detection By Micro-Clot Lysis and Chromogenic Assay. Presented at the 8th International Congress on Fibrinolysis, August 24-29, 1986, Vienna, Austria.

Conditioned medium (CM) from some human kidney cell cultures showed three to ten times higher activity in fibrin plate lysis (FPL) assays compared to micro-clot lysis (MCLA) and S2444 assays. To determine if scu-PA contributed to these differences, CM, samples and a purified preparation of scu-PA were preincubated with plasmin. Peak activation detected by S2444 occurred after 2.5 hours with plasmin at 3.2 ug/ml. High concentrations of plasmin induced a burst of activity in the first 15 minutes. In the MCLA, an activation lag phase was observed. The activity increase after 15 minutes preincubation with plasmin was 10% for scu-PA and 20% for CM.

28. Lewis, Marian L.; Damron, Kevin L. (Technology, Incorporated);

Barlow, Grant H. (Michael Reese Research Foundation); Morrison, Dennis R. (JSC): Electrophoretic Separation of Plasminogen Activator Producing Kidney Cells on the Space Shuttle. Presented at the Annual Conference on Biomedical Engineering, February 14-15, 1986, Houston, Texas.

On Space Shuttle flight 8 (STS-8), human kidney cells were separated in duplicate runs, designated Run 3 and 4, on the McDonnell Douglas continuous flow electrophoresis system (CFES). Postflight, subpopulations were cultured and assayed for urokinase (UK) and tissue plasminogen activator (t-PA) production. Separation profiles showed cells in 34 and 37 fractions in the two runs. In the ground control, cells were separated in 45 fractions. An apparent enhancement of resolution was achieved on STS-8 compared to the ground control. Substantial cell numbers were found over most of the range, 28-34 fractions, inflight and over only 14 mid-range fractions in the ground control separation. A battery of fibrinolytic and chromogenic assays for UK showed good reproducibility of separation of functionally similar cells in the two flight experiments. High UK producer cells were found within the same two or three fractions in the mid-mobility range for both flight and ground control. An enzyme linked immunosorbent assay (ELISA) for t-PA showed the highest t-PA producing fractions in the very high mobility range in both flight separations and in the mid-mobility range in the ground control.

29. Lin, Karl K. (Technology, Incorporated); and Reschke, Millard F. (JSC): The Use of the Logistic Model in Space Motion Sickness Predictions. Presented at Space Adaptation/7th International Man in Space Symposium, February 10-13, 1986, Houston, Texas.

Recently we have applied the stepwise Bayesian linear discriminant analysis procedure to a large non-astronaut motion sickness data base in an attempt to develop and cross validate a set of linear equations that can optimally predict the tested subjects' susceptibility to motion sickness in KC-135 parabolic flights. In this study we restricted our attention to the development of alternative prediction procedures. The logistic model, the most promising procedure among those alternatives proposed, differs from the other procedures in that it deals with criterion variables taking only values 0 and 1 (e.g., sick and nonsick), and that it assumes nonlinear relationships between the criterion variables and the predictors. As an alternative procedure, the logistic model will be applied to the same data set used in the discriminant analysis procedure. The prediction results from this alternative procedure will then be compared with those of the discriminant analysis procedure. In the predictions of sick or nonsick, and of vomit or nonvomit, a single-equation logistic model will be used. In the predictions of low, moderate, or high susceptibility, a two-equation logistic model will be used. Three parameter estimation methods (least squares, maximum likelihood, and Bayesian) and two iteration methods (Gauss-Newton, and Davidon) will be examined with the above logistic models. The logistic model should be able to improve the above predictabilities of the tested subjects' susceptibilities to motion sickness in KC-135 parabolic flights, if the relationships between the criterion variables and the predictors are in fact nonlinear.

30. Logan, James S.: An Approach to the Design of the Inflight Medical Care Delivery System Aboard Space Station. Presented at the Amerian Association for the Advancement of Science Annual Meeting, May 25-30, 1986, Philadelphia, Pennsylvania.

    The Medical Sciences Division at Johnson Space Center is in the early stages of requirements and systems definition for a modular inflight medical system known as the Space Station Health Maintenance Facility (HMF) which will provide preventive, diagnostic, and therapeutic capabilities. The goals of the HMF are to ensure the health and safety of the crew, prevent an unnecessary rescue, and increase the probability of success of a necessary rescue. HMF requirements derive from the operational constraints such as weightlessness, previous inflight medical experiences, and the projected "risk" of medical/surgical contingencies. The unique challenge of providing medical coverage for Space Station requires the development of low weight, low volume, highly automated medical hardware having wide application to terrestrial medical care.

31. McFadyen, Gary M.; Landry, Rudolph P. (Northrop Services); and Mieszkuc, Bernard (JSC): Engineering Evaluation of Clinical Diagnostic Instrumentation for the Space Station Health Maintenance Facility. Presented at the AIAA 11th Annual Technical Symposium, May 9, 1986, Houston, Texas.

    Several commercially available clinical diagnostics instruments have been identified as possible candidates for use in the Space Station Health Maintenance Facility, including the Kodak DT60 (with attached DTE Module), the Boehringer Mannheim Diagnostic (BMD) Reflotron, and the Clay Adams QBC, all desktop instruments weighing less than 20 kilograms each. An engineering evaluation was performed on each instrument to determine its compatability with the microgravity environment. All gravity dependent aspects were identified and eliminated by modification of the instruments. The instruments were then operated on the KC-135 parabolic flight during which approximately 30 sec/cycle of microgravity was available for testing. Through 40 parabolic cycles of operation, all instruments functioned properly.

32. Meehan, Richard T.; Bost, Kenneth; Neale, Laureen S.; Duncan, Ulric; Walsh, Pat (University of Texas Medical Branch); Taylor, Gerald R. (JSC); and Blalock, Ed: ACTH and Endorphin Receptors on Human Peripheral Blood Mononuclear Cells. Presented at the 5th International Conference on Automation of Diagnostic Cytology and Histology, May 30, 1986, Brussels, Belgium.

    Neuropeptide receptor positive cells from 50 subjects were identified by indirect immunofluorescence with monospecific antiserum against immunoaffinity purified ACTH and endorphin receptors by single and simultaneous multiparameter flow cytometry analysis. No diurnal variation was observed among 5 donors between 8 a. m. and 3 p. m. daily for 5 days ($13\pm1\%$ vs. $12\pm2\%$ for ACTHr and $17\pm1\%$ vs. $17\pm1\%$ for ENDOr positive cells). The percentage of unfractionated cells bearing ACTH and endorphin receptors in 4 donors was reduced by SRBC rosetting from $19\pm4\%$ to $4.4\pm4\%$ for ACTHr and $23\pm5\%$ to $6\pm3\%$ for ENDOr, whereas the monocyte and B cell fraction was increased to $24\pm4\%$ ACTHr and $25\pm15\%$ for ENDOr. This study indicates that ACTH and endorphin receptor positive peripheral blood mononuclear cells in humans exhibit

minimal diurnal variation and are expressed primarily on monocytes and B cells, but also on some T helper/inducer and T suppressor/cytotoxic cell populations.

33. Morrison, Dennis R.: Biotechnology Research and Alterations of Cell Function in Microgravity. Presented at the 1986 American Chemical Society Southwestern Region Annual Meeting, November 19-21, 1986, Houston, Texas.

Experiments on six flights of the Space Shuttle demonstrated advantages for electrokinetic separations performed in microgravity. A continuous flow electrophoresis (CFE) operated in microgravity can separate up to 700 times more protein per unit time than on Earth. The use of space electrophoresis, recirculating isoelectric focusing, and counter current distribution techniques are now being used to purify enzymes, hormones, and many cell types which secrete protein products. Kidney cells which produce urokinase and tissue-plasminogen activator, pituitary cells producing growth hormone, pancreatic beta cells and hybridoma cells have all been purified using these techniques. Recent space experiments have shown that cells attach 20-50% more readily to microcarriers, lymphocyte response to mitogens is reduced over 90%, release of growth hormone from pituitary cells is 60-70% less, bacterial replication is increased 3-4X, bacterial resistance to antibiotics is increased, and transfer of bacterial DNA is faster in microgravity. These all suggest that microgravity has a direct affect on certain cell functions and can provide unique insight into fundamental biodynamics.

34. Morrison, Dennis R.: Cell Growth-Secretion Technology in Space. Presented at the 22nd Annual Meeting of the Drug Information Association, June 1-5, 1986, Washington, DC.

NASA is developing unique bioreactors to culture mammalian cells in microgravity for space biology experiments and production of biological products. The first space bioreactor has been designed for microprocessor control, no gaseous headspace, circulation and resupply of culture medium, and slow mixing in very low shear regimes. Flight experiments will verify systems operation under microgravity conditions and measure the efficiencies of mass transport, gas transfer, oxygen consumption and control of low shear stress on human cells attached to microcarrier beads. Recent flight experiments have suggested major alterations to in vitro cell function and secretion under microgravity conditions. Experiments are investigating the altered response of T-lymphocytes to PHA mitogens and observation of changes in growth hormone secretions by pituitary cells. The threshold for biophysical effects of shear forces, pulsed flow, and other parameters are also being studied. New methods are being considered to study dynamic cellular systems which may be altered when living cells are suspended in microgravity or extended periods of time.

35. Morrison, Dennis R. (JSC): Space Biotechnology Research. Presented at the Annual Conference on Biomedical Engineering, February 14-15, 1986, Houston, Texas.

Bioprocessing experiments on six recent flights of the Space Shuttle

demonstrated enhanced separation of living cells and their secretory products. Continuous flow electrophoresis system (CFES) operated in microgravity can separate up to 700 times more protein per unit than on Earth. Medically important proteins include erthropoietin, unolcinase, and interferon. CFES also was used to isolate specific subgroups of kidney cells which produce urokinase, subgroups of pituitary cells that secrete growth hormone, and subgroups of pancreatic cells which secrete insulin. Space experiments using recirculating isoelectric focusing and other separation techniques are being developed along with a space bioreactor for microcarrier culture of human cells.

36. Morrison, Dennis R. (JSC); Grindeland, R. E. (Ames Research Center); and Hymer, W. C. (Penn State University): The Effects of Microgravity on the Release of Growth Hormone From Rat Pituitary Somatotrophs. Presented at the 1986 American Society for Gravitational and Space Biology Meeting, October 1-3, 1986, Charlottesville, Virginia.

  Growth Hormone (GH) producing cells from the rat pituitary flown on SL-3 were found to contain more intracellular GH but released less GH in culture. After transplantation into hypophysectomized rats, flight cells released only 50% of the GH into the receipient host compared to control cells. LC fractionation of culture media showed that flight cells did not release a high molecular weight GH variant that enriched in bioactivity. On STS-8, pituitary cells released 1/20 the amount of GH in vitro released on Earth in ground-based controls. Data to date implicate a direct microgravity-induced defect in GH secretion which may in turn be related to muscle and bone changes seen on the SL-3 rats.

37. Morrison, Dennis R. (JSC); Lewis, Marian L. (Technology, Incorporated): Transport, Harvest, and Attachment of Kidney Cells on Microcarriers in Micro-G. Presented at the American Society for Gravitional and Space Biology Meeting, October 1-3, 1986, Charlottesville, Virginia.

  On STS-7 and STS-8, human kidney cells were transported in special syringes and culture chambers to study the efficiency of harvesting cells from microcarrier beads and to determine if anchorage dependent cells could attach to microcarriers after mixing in micro-G. Attachment to Cytodex-3 microcarriers was studied at ambient cabin temperature (26°C). By 48 hours 37% of the beads had cells attached; however, cell proliferation rates could not be determined accurately. Experiments on STS-8 at 37°C showed that within 2.5 hours after mixing, 92% of single cells were attached to beads, compared to 40% in the ground controls, and cell proliferation was normal over 24 hours.

38. Neale, Lauren S.; Meehan, Richard T.; Duncan, Ulric; Ramsey, Keith (University of Texas Medical Branch); and Taylor, Gerald R. (JSC): Effects of Hypoxia on Human Lymphocyte Activation. Presented at the 5th Inernational Conference on Automation of Diagnostic Cytology and Histology, May 30, 1986, Brussels, Belgium.

  Peripheral blood mononuclear cells were obtained from 7 subjects at sea level (SL), and at hypobarically-simulated altitudes of 7,500 ft (ALT 1) and 25,000 ft (ALT 2) during a 7-week decompression chamber study (Operation Everest II). Circulating leukocyte subpopulations were identified by flow cytometry using fluoresceinated monoclonal antibodies. In vitro pokeweed mitogen (PWM) and phytohemagglutinin

(PHA) stimulated cell populations were evaluated for ^{35}S Methionine incorporation at 24 hours, tritiated Thymidine uptake at 72 hours, and NK cytotoxicity at 24 hours by ^{51}Cr released from K562 cells. Under the most stressing condition, an increase in the percentage of monocytes ($9\pm1\%$ SL vs. $19\pm3\%$ ALT 2) was observed, although percentages of T helper/inducer, T suppressor/cytotoxic, and B cells remained constant in the peripheral circulation. NK cytotoxicity was unimpaired in 6 of 7 subjects at ALT 2 despite reduced PHA (but not PWM) stimulated protein synthesis at 24 hours and reduced blastogenesis at 72 hours. This study indicates that hypoxia may impair host resistance in humans by inducing immunoregulatory abnormalities such as an increase in monocytes in the peripheral circulation and a decrease in the ability of lymphocytes to respond to mitogenic challenge.

39. Putcha, Lakshmi (Northrop Services); Cintron, Nitza M. (JSC); Vanderploeg, James M.; Chen, Y.; and Dardano, Joseph R. (Northrop Services): Comparative Concentration Profiles of Acetaminophen in Plasma and Saliva of Normal Subjects. Presented at the World Conference on Clinical Pharmacology and Therapeutics, July 27-August 1, 1986, Stockholm, Sweden.

   Current investigation is aimed at evaluating the pharmacokinetic application of salivary concentration profiles of acetaminophen. Following oral administration of 650mg acetaminophen to five normal subjects, salivary drug levels of acetaminophen were identical to those of plasma with an S/P ratio of 1 and a correlation coefficient greater than 0.9 during all phases of drug disposition. Absorption rate constants and elimination half-lives calculated from plasma and saliva profiles ranged between 3.5 to 4.6 h^{-1} and 1.8 to 2.1 h respectively. Area under the curve for plasma and saliva (37 ± 16 and 38 ± 15 ug.h/ml respectively) were also in close agreement. These results indicate that salivary concentration profiles of acetaminophen can be successfully employed for therapeutic monitoring as well as for pharmacokinetic and bioavailability estimations of the drug.

40. Reschke, Millard F. (JSC); Anderson, D. J. (University of Michigan); and Homick, Jerry L. (JSC): Vestibulo-Spinal Response Modification as Determined with the H-Relfex During the Spacelab-1 Flight. _Experimental Brain Research_, Vol. 64, pp. 367-379, 1986.

   The H-reflex, measured inflight, was recorded along with vestibulospinal EMG from the gastrocnemius and self-motion reports were obtained in response to a sudden earth vertical fall. Preflight, inflight and postflight motion sickness reports were also recorded, and related to the H-reflex data. The results indicated that early inflight H-reflex amplitude was similar to that recorded preflight, but that measurements obtained later in the flight (day seven) did not show a change in potentiation as a function of the different drop to shock intervals. Immediate postlfight H-reflex response in three of the four astronauts tested showed a rebound effect. Postlfight gastrocnemius EMG in response to the sudden fall did not show a significant change from preflight values. However, one crewman who was tested early postflight did show an increase in EMG activity in response to the sudden fall. This immediate postflight effect returned to baseline rapidly. Self-motion perception obtained inflight suggested that the early inflight drops were perceived like those pre-

flight. Drops later inflight were described as sudden, fast, hard and
translational in nature. Immediately postflight the drops were per-
ceived like those late inflight, and the astronauts said that they did
not feel as though they were falling, rather that the floor came up to
meet them. Post hoc H-reflex amplitude, both preflight and post-
flight, was related to inflight space motion sickness.

41. Reschke, Millard F.; Parker, D. E.; and Vanderploeg, James M.: Eye
    Countertorsion to Static Tilt in Orbital Flight. Presented at the the
    1986 Aerospace Medical Association Scientific Meeting, April 20-24,
    1986, Nashville, Tennessee.
       Counterrolling of the eyes with the neck flexed at tilts of 0, 15,
    30 and 60 degrees relative to the trunk was measured both CW and CCW
    in 6 astronauts using the flash after-image method. A neck brace re-
    quiring whole body tilt was used as control. Measurements were made
    on the first day in flight, and followed with measurements on the 2nd,
    3rd and 5th days of flight. A minimum of 3 measurements were obtained
    at each day of the flight. Both tilt angle and target displacement
    were counterbalanced. Results from Shuttle flights 61-C, 61-E, will
    be discussed. It is hypothesized that the normal otolith induced tor-
    sional eye movement will be absent early in the flights due to the
    loss of a directional gravity gradient. As the flight progresses,
    neck receptor information will replace otolith input and counterroll-
    ing will be present.

42. Santy, Patricia A.: On Being a Psychiatrist and Flight Surgeon at
    NASA. Presented at the LAC/USC Medical Center, October 14, 1986.

43. Sauer, Richard: Challenges to Food Service in Space. Presented at the
    Institute for Food Technologists Meeting, January 1986, Newark, New
    Jersey.

44. Sauer, Richard L. (JSC); Flanagan, D. T.; and Willis, C. E. (Technology,
    Incorporated): Disinfection Needs for Space Station: Presented at
    Chemical Disinfection III, April 3-5, 1986, Binghamton, New York.
       The combination of unique characteristics associated with space
    flight, closed environments, and the planned Space Station presents
    special disinfection problems for life support system designers. For
    design purposes, the Space Station will have a 90 day tour of duty, an
    unlimited useful hardware lifetime, and a 28 day time to rescue. Be-
    cause of the isolated nature of this closed environment, the indefi-
    nite length of occupancy, and potential for microbial proliferation,
    provisions must be made for maintenance, monitoring, and restoration
    of sanitary conditions inflight without the aid of ground interven-
    tion. Areas of specific need are internal cabin surfaces, cabin at-
    mosphere (normal deposition mechanisms are absent), water systems,
    waste management and personal hygiene systems, food systems, and fil-
    ter and adsorbant beds. Specific requirements and related disinfec-
    tion options are described in detail.

45. Sauer, Richard L. (JSC); and Murray, R. W. (General Electric Company):
    Integrated Waste and Water Management System. Presented at the
    Intersociety Conference on Environmental Systems, July 14-16, 1986,
    San Diego, California.

Several years ago, an integrated waste and water management system was developed under a joint Atomic Energy Commission, Air Force, and NASA. The system utilized distillation and catalytic oxidation processes for purifying waste water and microbial digestion and incineration for waste solids disposal. The system successfully operated for 200 days continuously handling a 4-man equivalent of urine, feces, wash water, condensate, and trash. This system was reviewed for applicability, updating, and possible synergism with other life support systems. This paper discusses the synergistic aspects of thermal integration, commonality of design, and new technology applied to advanced life support systems.

46. Sauer, Richard L. (JSC); and Rappole, Clinton L. (University of Houston): Food for Astronauts in Space. Presented at the Annual Meeting of the Society for the Advancement of Food Service Research, April 3, 1986, St. Louis, Missouri.

47. Taylor, Gerald R. (JSC); Hunter, Norwood R. (Technology, Incorporated); and Winkler, Don G. (Perceptive Systems): Digital Imaging in the USA Space Station. Presented at the 5th International Conference on Automation of Diagnostic Cytology and Histology, May 30, 1986, Brussels, Belgium.

The inflight digitizing facility (IDF), which may be operational in as many as 3 of 4 Space Station habitation modules, supports the Health Maintenance Facility (HMF), where imaging will be used for clinical analyses such as microbial identification, echocardiology, blood cell differentials, urine sediment analysis, and fundoscopy. An IDF will also support the Human Research Facility (HRF) with the above capabilities plus other special activities for plant, animal, and human research. A third IDF may also be used in the materials processing module to evaluate activities such as crystal growth and cell development or to detect morphological alterations. Data will be collected, displayed, analyzed, and stored in orbit. In addition, digital data will be relayed to ground laboratories for processing. Subsequently, experts will be able to communicate with Space Station personnel for continued data collection and inflight analysis.

48. Waligora, James M.; and Horrigan, David J., Jr.: The Effect of Extended O_2 Prebreathe on the Incidence of Altitude Decompression Sickness and Venous Gas Bubbles. Presented at the 7th International Man in Space Symposium, February 10, 1986, Houston, Texas.

The purpose of this study was to determine the effect of extended O^2 prebreathe on symptom and bubble incidence during decompressions simulating extravehicular activity. Venous bubbles were detected in 18 of 38 subjects decompressed after a 6 hour prebreathe. Four of these subjects reported symptoms of altitude decompression sickness. No symptoms or bubbles were detected in eight subjects who had prebreathed 8 hours. The incidence of symptoms and bubbles when combined with prior data on 3.5 and 4.0 prebreathes showed an inverse correlation to prebreathe time. The incidence of symptoms was higher than has been reported exposing subjects to decompression of shorter duration with less activity.

49. Waligora, James M.; Horrigan, David J., Jr. (JSC); Conkin, J.; and
    Gilbert, J. H. (Technology, Incorporated): Incidence of Symptoms and
    Venous Gas Bubbles in Male and Female Subjects After Decompression.
    Presented at the 1986 Aerospace Medical Association Scientific Meet-
    ing, April 20-24, 1986, Nashville, Tennessee.

    Retrospective studies have suggested a greater susceptibility to
    altitude decompression sickness in females. In recent tests females
    have been included in test protocols investigating altitude decom-
    pression sickness. This paper reports on the incidence of symptoms
    and bubbles in these tests as a function of the sex of the subject.
    In the combined studies with 67 exposures, there was a total incidence
    of mild symptoms of decompression sickness of 8% and of venous gas
    bubbles of 21%. For male subjects the incidences were 6% symptoms and
    23% bubbles; for female subjects the incidences were 9% symptoms and
    18% bubbles. There was no statistical difference in the incidence of
    symptoms or venous gas bubbles between males and females.

50. Willis, Charles E. (Technology, Incorporated); and Sauer, Richard L.
    (JSC): Reevaluation of Metabolic Performance Results From Skylab 4
    Experiment M171. Presented at the Space Adaptation Symposium,
    February 10-13, 1986, Houston, Texas.

    Reevaluation of the data from Skylab Medical Experiment M171 reveals
    a statistically significant inflight elevation of the respiratory quo-
    tient of approximately five percent over preflight and postflight val-
    ues. The source of the RQ increase might be dietary because the cal-
    culated RQ from space food is .967 compared to .83 of the normal ter-
    restrial diet. The inflight RQ may be affected by the residual iodine
    bactericide present in the potable water, or may be a minifestation of
    abnormal thyroid funcitons. Thyroid stimulating hormone levels (TSH)
    were elevated for at least 14 days postlfight, though thyroxine levels
    increased only slightly, and triiodothyronine (T3) remained constant.
    Ground tests could be devised which could isolate the source of RQ
    elevation.

Solar System Exploration Division

1. Agresti, David G. (University of Alabama); Morris, Richard V. (JSC); Newcomb, Jeffrey H. (University of Alabama); and Lauer, Howard V., Jr. (Lockheed Engineering and Management Services Company): Spectral Properties of Selected Soils from the Dry Valleys of Antarctica. Presented at the 17th Lunar Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 3-4.

2. Badhwar, Gautam D. (JSC); Gargantini, C. E.; and Redondo, F. V. (Comicion Nacional de Investigaciones Espaciales): Landsat Classification of Argentina Summer Crops. Remote Sensing of Environment, Vol. 21, pp. 111-117, February 1987.

   A Landsat multispectral scanner and multitemporal classification approach based on three features derived from the greenness profile has proved very effective in separating and identifying corn, soybeans, and other ground cover classes in the United States. The objective of this study is to investigate the separation of summer crops in Argentina, using the same greenness profile features that have proved effective in the U.S. corn belt. The area chosen for this study is a much more complex cropping practice area in the northwest corner of Buenos Aires province in Pampa Humeda, where corn, soybean, sorghum, sunflower, and pastures are cultivated. It is shown that the profile features can provide very effective separation, except in the case of corn from sorghum. Separation between corn and soybeans was found to be greater than in the U.S. This study suggests that the automatic, unsupervised classification approach developed in the U.S. can be used for summer crop area estimation in Argentina with relatively minor modification.

3. Badhwar, Gautam D.; MacDonald, Robert B. (JSC); and Mehta, Naresh C. (MIT/Lincoln Laboratory): Satellite-Derived Leaf-Area-Index and Vegetation Maps as Input to Global Carbon Cycle Models--A Hierarchical Approach. International Journal of Remote Sensing, Vol. 7, No. 2, pp. 265-281, 1986.

   The key role of vegetation in the global carbon cycle is clearly demonstrated by the semiannual variations of the carbon dioxide concentration in a given hemisphere. The primary variables of interest are the net primary productivity and the biomass on a global scale, and the key to their estimation is the leaf-area index (LAI). A global determination of the LAI is practical only with remote sensing satellite systems. A hierarchical approach to obtaining a LAI map of deciduous boreal forests, which contain a significant part of the total global carbon reservoir, using satellite data is presented. The results show that it is very important to understand the nature of the basic physical interaction of solar radiation with canopy biophysical characteristics, if meaningful estimates of these variables are to be made. This understanding has been achieved using ground, helicopter, and aircraft measurements made very near the area covered by the Landsat satellite.

4. Barrett, Ruth A.; Rietmeijer, Frans J. M. (Lockheed Engineering and Management Services Company); Kessler, Donald J.; McKay, David S.; and Zook, Herbert A. (JSC): Hypervelocity Impact Features on the Returned Solar Max Satellite Main Electronics Box (MEB) Thermal Blanket. Presented at COSPAR XVI, June 30 - July 12, 1986, Toulouse, France. <u>Abstracts of the 26th Plenary Meeting of the Committee on Space Research</u>, p. 176.

Returned surfaces of the MEB thermal blanket from the Solar Max Satellite offer an opportunity to examine debris and micrometeoroids in the near-Earth environment. Impact features are craters (up to 140μm in diameter) and penetration holes (O: 80-500μm). The craters have generally smooth, raised, and overturned rims and textured interiors. The holes have almost identical, overturned rims on front and back sides of layer 1 suggestive of hypervelocity impact. Beneath a hole on layer 2, a spray pattern of pits and small holes or a textured surface is generally present. When a projectile penetrated layer 2, the holes are typically irregular. Many particles associated with impact features are projectile residue. Micrometeorite residue is present in 12 out of 39 impact features. The remaining impact features contain particles which show a combination of Ti, Si, Zn, K and Cl. Except for Cl, this combination of elements is consistent with known spacecraft paint pigments. Paint particles in 19 impact features suggest that these features may have been formed by orbiting paint impacts.

5. Barrett, Ruth A.; Schramm, L. S. (Lockheed Engineering and Management Services Company); Warren, J. L. (Northrop Services); Zook, H. A.; and McKay, David S. (JSC): Impact Features and Projectile Flux on Returned Solar Max Material. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 26-27.

6. Barrett, Ruth A. (Lockheed Engineering and Management Services Company); and Zolensky, Michael E. (JSC): Compositional-Crystallographic Relations for Polybasite. Presented at the 99th Annual Geological Society of America Meeting, November 10-13, 1986, San Antonio, Texas. <u>GSA Abstracts with Programs</u>, Vol. 18, No. 6, p. 535.

During an ore mineralogy study of the DeLamar Silver Mine in Owyhee County, Idaho, polybasite was found to contain up to 7.8 wt% Se. Compositional and crystallographic data were critically evaluated and augmented with new microprobe and XRD data. Polybasite exists as a fully disordered monoclinic cell, with approximate cell dimensions of a=13, b=7.5, c=12A, and β=90.0°, called the 1-1-1 cell, an intermediate 2-2-1 cell, and a doubled, fully ordered 2-2-2 cell. The 2-2-1 cell is predominant at the DeLamar Silver Mine. The unit cell dimensions of polybasite increase regularly with increasing amounts of Se. The intermediate 2-2-1 polybasite cell is stable over the entire compositional range examined in this study. In contrast, the fundamental 1-1-1 cell was found only in polybasites with 6.36 wt% or greater Se, and the fully doubled 2-2-2 cell was only encountered for polybasites containing no Se. Two explanations for this are that (1) the polybasite containing high Se cooled quickly, quenching the high temperature

disordered 1-1-1 and intermediate 2-2-1 polybasite cells, or (2) the presence of Se in polybasite inhibits full ordering to the 2-2-2 cell.

7. Blanchard, Douglas P., editor: <u>Lunar News</u>.   Lyndon B. Johnson Space Center, Houston, Texas, 1986.

A triennial publication of facts and opinions regarding lunar sample study, lunar geochemical orbiter, and lunar base activities.

8. Blanchard, Douglas P.: Plans for a 1996 Mars Sample Return Mission. Presented at the National Academy of Sciences, July 22, 1986, Washington, DC.

Mars sample return represents a second-in-a-civilization opportunity to reap rich scientific rewards from ambitious space missions which return samples from another solar system body. As we have learned more about the red planet, our scientific questions have become better defined but far more numerous. Viking showed us that life on Mars is extremely unlikely, but were there ever lifeforms there? There is clear evidence for flowing water on the surface of the planet, but where is that water now? Mars has been a hot and volcanically active planet; when did it run out of heat and become inactive? Its atmosphere is very thin yet highly evolved; what has happened to the atmosphere? Mars has geologic features that are unique in our solar system such as the 26 km high Olympus Mons, the 7 km deep Valles Marinaris and the curious cratered and smooth plain terranes. What planetary processes have presented us with this Martian puzzle? The answers to many of these questions can be found in the careful study of samples from the Martian surface.

9. Blanchard, Douglas P.: Supporting Planetary Missions: The Space Station Role. Presented at the American Astronomical Society International Conference, Nov. 7, 1985, San Diego, California.

This discussion centers on three areas of interaction of the Space Station with ambitious planetary missions: staging and launching from Space Station, recovery of the returning spacecraft and samples to Space Station, on-orbit sample examination and quarantine at Space Station. Advantages and disadvantages of the role of Space Station in each of these situations are discussed and potential design issues and requirements for Space Station planning are identified. Sample return missions are highlighted in this discussion because they are among the most ambitious missions and place the most severe requirements on the Space Station.

10. Blanford, G. E. (University of Houston-Clear Lake); Rietmeijer, Frans J. M.; and Schramm, L. S. (Lockheed Engineering and Management Services Company); and McKay, David S. (JSC): Extraterrestrial Olivines Brought Back From Space. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 56-57.

11. Bogard, Donald D.: Does Venus' Atmosphere Contain a Terrestrial-like Component? Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 62-63.

We utilized various three-element correlation plots to examine sev-

eral possible explanations for the volatiles in Venus' atmosphere e.g., solar-meteorite and solar-Earth mixtures, lunar-solar and lunar-Earth mixtures, extremely fractionated solar, and low-temperature fractionation produced by adsorption and clathrate formation. C on Venus is consistent with a solar-Earth or lunar-Earth mixture but not with two component mixtures involving meteorite volatiles. N is consistent with a variety of possible mixtures or with low-temperature processes that concentrate volatiles. Kr on Venus is not consistent with a solar-meteorite mix. Xe on Venus is consistent with two component mixtures only if its abundance is actually several factors lower than the upper limit reported. Ne appears consistent only with an extreme lunar-like fractionation of solar composition. N, Ar, Kr, and Xe would be consistent with all of Venus' volatiles having been derived from a lunar-like, but extremely fractionated solar component, but C would be in excess relative to this fractionation, and Ne, deficient. We suggest that the most consistent explanation of the volatiles in Venus' atmosphere is that they are a mixture of Earth-like component, which contributes most of the C, N, and nearly all of the Ar and Ne. This suggests that Venus and the Earth contain a common volatile component in comparable concentrations.

12. Bogard, Donald D.; Horz, Friedrich; and Johnson, Pratt,: Shock-Implanted Noble Gases: An Experimental Study With Implications for the Origin of Martian Gases in Shergottite Meteorites. Presented at the 49th Annual Meeting of the Meteoritical Society Meeting, September 22-25, 1986, New York; and published in Journal of Geophysical Research, Vol. 91, No. B13, pp. E99-E114, November 30, 1986.

The existence of trapped gases, apparently shock-implanted from the Martian atmosphere into certain phases of the EETA79001 shergottite-meteorite, raises important questions as to the mechanism of gas implantation and whether the implanted gas has been mass fractionated. To study the phenomenon of shock-implantation of gases, we artificially shocked whole-rock and powder samples of a terrestrial basalt to pressures of 2-35 GPa in the presence of controlled gas mixtures ranging from 10^{-4} to 3 atmospheres. Experimental data are consistent with shock-implantation of Martian gases without mass fractionation into shock-melted phases of EETA79001; the progenitor of these melts may have been porous fragmental material.

13. Bogard, Donald D.; Horz, Friedrich; Johnson, Pratt; and Schmidt, R.: Noble Gases Implanted by Artificial Shock: Implications for Trapped Martian Gases in the EETA79001 Meteorite. Presented at the Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 64-65.

14. Carr, R. H; (National Research Council); Gibson, Everett K. (JSC); Rietmeijer, Frans J. M. (Lockheed Engineering and Management Services Company); Grady, M. M.; Wright, I. P.; and Pillinger, C. T. (The Open University, Milton Keynes, England): Characterization of Carbonaceous Materials in Interplanetary Dust Particles. Presented at the 49th Annual Meteorological Society Meeting, September 22-25, 1986, New York, New York.

15. Cintala, Mark J.; Horz, Friedrich (JSC); and See, Thomas H. (Lockheed

Engineering and Management Services Company): Impact Experiments on The NASA KC-135 Reduced Gravity Aircraft: Early Results. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 131-132.

16. Clark, Benton C.; Amundsen, Ruth (Martin Marietta Aerospace Company); and Blanchard, Douglas P. (JSC): Sampling the Cometary Nucleus. <u>Proceedings of the ESA Symposium on Comet Nucleus Sample Return</u>, July 15, 1986, Canterbury, England.

Three modes are possible for obtaining samples of cometary material: remote sampling, hover mode sampling, and landed (anchored) sampling. For each mode, trade-offs involving complexity, risk factors, and cost must be analyzed for the spacecraft and the sampling system. Flyby results for P/Comet Halley indicate heterogeneity in the cometary nucleus that could dictate sampling at several different locations. Coring drills, drive tubes, and specialized mantle sampling devices must operate at cold temperatures (100 to 189 K) without heating the sample. Sample selections must be accommodated by the sample return canister, which must also be protected from thermal excursions.

17. Colson, Russell O.; Taylor, Lawrence A. (University of Tennessee); McKay, Gordon A. (JSC): Predictive Thermodynamic Modeling for Trace Element Partitioning in Magmatic Systems. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 144-145.

18. Coulson, Kinsell L. (University of California/Davis); Whitehead, Victor S. (JSC); and Campbell, Charles (Lockheed Engineering and Management Services Company). Polarized Views of the Earth from Orbital Attitude. Presented at the Society of Photo-Optical Instrumentation Engineers Ocean Optics Meeting, March 31 - April 4, 1986, Orlando, Florida. Published in <u>SPIE</u>, Vol. 637, pp. 35-41, 1986.

In a program for utilizing both intensity and polarization of light emerging to space from the top of the atmosphere for remote sensing of the earth's surface, polarized images have been obtained in four flights of the Space Shuttle. The photos were taken with a pair of boresighted and synchronized Hassleblad 70mm cameras fitted with polarizing filters, the filters being oriented horizontally on one camera and vertically on the other. STS 51-A yielded more than 100 pairs of black and white images in polarized light, and similar pairs were obtained with color film on STS 51-G, STS 51-I, and STS 61-A missions. Selected image pairs have been digitized, the vertically and horizontally polarized images brought into registration, and the resulting signals processed to give images in degree of polarization, as well as intensity, for different sun-scene-observer geometries and various continental and oceanic features. Many of the scenes show surface properties more distinctly in degree of polarization than in simple intensity.

19. Cour-Palais, Burton B.: Preliminary Hypervelocity Impact Calibration of Solar Max Thermal Blankets and Louvers. Presented at the Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published inin <u>Lunar and Planetary Science XVII</u>, p. 146.

A preliminary calibration of the impact related holes found in the Solar Max Mission satellite thermal blankets and louvers was performed at the JSC. The small light-gas gun (1.78mm bore) was used to sabot-launch projectiles ranging from 110 to 400 micrometers, at speeds between 5.7 and 6.8km/s. Projectile materials used were glass and aluminum oxide. The test samples consisted of unflown spare aluminum louvers of 99.45% pure aluminum (1145-H14), 140 micrometers thick, and thermal blanket targets consisting of 14 layers of 6.3 micrometer aluminized Mylar, interspersed with a dacron mesh. These were sandwiched between a 25 micrometer and a 76 micrometer Kapton layer on each side. The outer surfaces of the Kapton layers were gold and copper colored respectively, but their insides were aluminized. This abstract deals with the results of the hole size versus the size of the impacting particle only.

20. Dasch, Julius (National Research Council); Shih, C-Y; Bansal, B. M.; Wiesmann, H. (Lockheed Engineering and Management Services Company); and Nyquist, L. E. (JSC): Isotopic Provenance of Aluminous Mare Basalts From the Fra Mauro Formation. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 150-151.

21. Dietrich, John W.; and Amsbury, David L.: Incised Meanders: A Normal Product of Stream Erosion. Presented at the 99th Annual Geological Society of America Meeting, November 10-13, 1986, San Antonio, Texas.
    Sinous valleys cut into bedrock are common in many arid and semiarid regions. Sinuosity greater than 1.50, the lower limit for applying the term "meander" in alluvial streams, is common. Some streams that drain basins smaller than 5 square miles have small, well-developed, incised meanders. Within areas of uniform bedrock, meander size increases as stream flow (inferred from drainage basin area) increases. Photographs from space document these features in diverse terrain. Maps plus observations from aircraft and in the field provide additional data for areas in the southwestern United States. On the Edwards Plateau, incised streams with drainage basins of 5 to 10 square miles exhibit meander lengths of 1/5 to 1/4 mile; streams draining 70 square miles exhibit meander lengths of about one mile. Incised meanders in the Guadalupe Mountains are of similar size in streams draining less than 5 square miles; but they increase to only 1/2 mile in a drainage basin of 90 square miles. Tributaries of the Escalante River in south-central Utah exhibit meander lengths only 1/6 the size of those on the Edwards Plateau for similar drainage areas. The decrease in meander size westward may relfect the decrease in rainfall.

22. Duke, Michael B.: Lunar Base as an International Infrastructure Project. Presented to the International Federation of Institutes for Advanced Study, July 7-11, 1986, Anchorage, Alaska.
    A number of problems need to be solved in order that a lunar base can become a productive and eventually self-sufficient entity. Technical problems include reducing the high cost and increasing the safety of Earth to orbit transportation; creating the infrastructure of space stations and reuseable space vehicles that would service the Earth-Moon transportation system; and establishing the technology for

utilizing lunar resources. Political/social problems to be solved include the question of who benefits from the utilization of lunar resources, those who invest or the entire Earth, independent of the investment; and, what are the mechanisms of financing such undertakings. An international consortium may be an effective way to approach the problems, particularly if the consortium can find novel ways to address and delineate the responsibilities that belong to Governments and to private entities. The consortium might build and operate the base, but not the required space transportation system (other than perhaps special purpose vehicles). In this manner, the consortium would be free to contract with space transportation system entities (NASA, ESA, USSR, private) that are available to support the demands of the enterprise. Such a program would maintain a strong incentive for competition to provide low cost and safe Earth-Moon transportation.

23. Duke, Michael B.: Manned Mars Missions Overview. Presented at the Mars Conference, July 21-23, 1986, Washington, DC.

Human excursions to Mars are a long term goal of the space programs of the world. Utilizing technology currently under development, such missions can be anticipated in the 20-40 year planning timeframe. The development of an operational space infrastructure, including Earth to orbit launch capacity, low earth orbit (LEO) servicing capability, and orbital transfer vehicle (OTV) technology are on the critical path to Mars. Answers to operational questions, principally dealing with long term life support issues (is artificial gravity needed?), mission autonomy, and planetary protection need to be obtained before Mars spacecraft can be designed for early missions. The goal of sustained outposts on Mars requires attention to questions of routine space transportation system performance, the development of a robust space infrastructure, and the development of self-sufficiency at Mars. The prospect of such ventures opens opportunities for many technological innovations and the potential for international cooperation on a scale not previously undertaken in the exploration of space.

24. Duke, Michael B.: Rationale for an Integrated Moon/Mars Exploration Program. Presented at the 33rd Annual Meeting of the American Astronautical Society, October 26-29, 1986, Boulder, Colorado.

Although it is possible to design manned missions to Mars that do not involve prior lunar missions, a strategy that includes the development of a lunar base before or concurrent with the Mars program offers potential benefits from space infrastructure development, space operations experience, and utilization of lunar materials for propulsion. Common utilization of infrastructure elements (e.g., orbital transfer vehicles, space operation center modules) is emphasized in this approach. Common utilization of transportation elements such as spacecraft lunar and Mars landers does not appear to provide significant benefits.

25. Duke, Michael B.: The Role of a Lunar Base in a Space Economy. Presented at Symposium '86, September 22-24, 1986, Atlantic City, New Jersey.

Products for space propulsion and space construction are readily

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available from known lunar materials, and become competitive with
Earth-derived resources when the market requires on the order of 1000
metric tons per year in low earth orbit. The minimum transportation
cost of lunar materials to low earth orbit, utilizing conventional
technology (cryogenic propellant rockets), eventually might be in the
range of $5/KG (compared to $3000/KG now from Earth); advanced tech-
nologies such as electromagnetic launchers can reduce these costs fur-
ther. As transportation costs from Moon to LEO delcine, the variety
and quanitity of lunar materials utilized in LEO will grow. Thus, lu-
nar resources could be the basis for a major expansion of LEO activ-
ity. Lunar oxygen, iron, aluminum, and titanium are highly concen-
trated. Other essential elements, such as hydrogen and carbon, are
dispersed. It has not been demonstrated conclusively that they can be
extracted economically at any market level; the size of the necessary
mining operations is tens of square kilometers/year. These opera-
tions, if they prove economic, will dominate the development of lunar
surface activities, due to their demands on equipment and people.
Once a foothold has been established, many other economic activities
can be envisioned for the lunar base. With diminished transportation
costs, tourism may be feasible. The lunar surface may become a loca-
tion for food production for and waste recovery from space operations.
The lunar base could be a key transportation hub in the human explora-
tion of Mars.

26. Duke, Michael B.: Symposium '86: Lunar Development and Magnetic Levi-
tation Transportation Systems (Keynote Address). Presented at Sym-
posium '86, September 22-24, 1986, Atlantic City, New Jersey.
   At a lunar base, the challenge is to adapt to and modify an existing
environment by use of lunar materials. It is a major challenge, and a
principal focus of this conference, along with magnetic levitation for
surface transportation. The concepts interact at a variety of levels.
Maglev should be uniquely compatible with operations in the lunar
vacuum. Low-cost Moon to space and space to Moon transportation is
key to the long-term viability of a lunar export economy. Another
thread that ties maglev and the lunar base together is the general
advancement of the relevant technologies of materials, structures,
electronics and computers that will support both ventures.

27. Duke, Michael B.; McKay, David S.; and Mendell, W. W.: Site Selection
for a Lunar Base: Science Considerations. Presented at the 17th
Lunar and Planetary Science Conference, March 17-21, 1986, Houston,
Texas. Abstract published in Lunar and Planetary Science XVII, pp.
188-189.

28. Gibson, Everett K. (JSC); Carr, L. P.; Gilmour, I.; and Pillinger, C. T.
(The Open University, Milton Keynes, England): Carbon and Nitrogen
Isotopic Analysis of Archean Sediments: Evidence of Earth's Early
Atmosphere? Presented at the 8th International Conference on The
Origin of Life, and the 5th ISSOL Meeting, July 21-25, 1986,
Berkeley, California.
   Stepwise heating studies of the Archean sediments reveal a wide
variety of C and N isotopic compositions. Compositions for the gases
released at elevated temperatures are essentially identifical with
those of modern-day atmosphere. Supporting evidence that the argon

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trapped within the sediments is "ancient" strongly suggests that the trapped carbon and nitrogen are samples of the trapped early atmosphere components. If this is the case, the isotopic compositions of the C and N components present in the Archean atmosphere are essentially identical to those present today despite the fact that the atmosphere has probably changed from an essentially neutral composition, (e.g., CO_2, N_2, H_2O) to an oxidizing composition (e.g., N_2, O_2, H_2O, Ar).

29. Gibson, Everett K., Jr. (JSC); Carr, L. P.; Gilmour, I.; and Pillinger, C. T. (The Open University, Milton Keynes, England): Earth's Atmosphere During the Archean as Seen From Carbon and Nitrogen Isotopic Analysis of Sediments. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 258-259.

    From our studies of Archean sediments it can be seen that the C and N isotopic compositions for the gases released at elevated temperatures are essentially identical to those of modern-day atmosphere. The supporting evidence that the argon trapped within the sediments is "ancient" argon strongly suggests that the trapped carbon and nitrogen are samples of the trapped early atmosphere components. If this is the case, the isotopic compositions of the C and N components present in the Archean atmosphere are essentially identical to those present today despite the fact that the atmosphere has probably changed from an essentially neutral composition (CO_2, N_2, H_2O) to an oxidizing composition (N_2, O_2, H_2O, Ar).

30. Gooding, James L., editor: Antarctic Meteorite Newsletter. Lyndon B. Johnson Space Center, Houston, Texas, 1978-86.

    A periodical issued by the Antarctic Meteorite Working Group to inform scientists of the basic characteristics of specimens recovered in the Antarctic.

31. Gooding, James L.: Carbonanceous Chondrites: Thermal Analysis by Differential Scanning Calorimetry. Abstract published in Lunar and Planetary Science XVII, pp. 269-270.

    Low-temperature DSC can provide information about aqueous diagenetic processes on meteorite parent bodies whereas high-temperature DSC can be used to evaluate bulk mineralogical properties of various types of meteorites. Upon cooling, wet Murchison (water/meteorite mass ratio = 0.57) crystalized water ice near 260 K, followed by solidification of a more freeze-resistant water complex, and decrease in heat capacity. Upon heating, frozen Murchison produced liquid water, followed by thermal decomposition of a water complex. Heat capacity of the unfrozen mixture was substantially higher than that of the frozen precursor. Both the cooling- and heating-curve transitions were reproducible through several temperature cycles. Persistence of "unfrozen" water at temperatures far below 273 K supports the proposition that aqueous alteration on the Murchison parent body might have occurred at very low temperatures.

32. Gooding, James L.: Clay-Mineraloid Weathering Products in Antarctic Meteorites. Geochimica et Cosmochimica Acta, Vol. 50, pp. 2215-2223, 1986.

Clay mineraloids are associated with gypsum, K-Fe-sulfates (possible jarosite), cryptocrystalline rust, and possible with zeolites and/or (secondary) alkali feldspars as terrestrial weathering products in stony Antarctica. Weathering formed fracture fillings in fusion crusts of eucrites EETA79004 and EETA79005, diogenites ALHA77256 and EETA79002, shergottite EETA79001 and H5-chondrite ALH82102 and decompositon products of glass and plagioclase in interior samples of a-chondrites. Clay mineraloids displayed massive to incipient-vermicular forms with elemental compositions that suggest smectite- and mica-like phases. Deposits were too small to yield pure material for phase identification although x-ray diffractometry and differential scanning calorimetry of bulk samples suggested that the clay mineraloids were not well crystallized. "Hydrocryogenic" diagenesis can initiate clay-mineral formation on timescales of 10^4-10^6 y even with only limited supplies of liquid water. Cosmochemists must take care not to confuse possible weathering-induced elemental and isotopic fractionations in Antarctic meteorite samples with signatures of pre-terrestrial "cosmic" processes. Given proper sample selection and testing, though, occurrence of clay-mineraloid and other weathering products should probably not impede progress in studies of Antarctic meteorites.

33. Gooding, James L.: Condensation of Frosts on Martian Dust Particles. In Lee, S., editor: Meca Workshop on Dust on Mars, II, LPI Tech. Rept. 86-09, p. 23-25, Lunar and Planetary Institute, Houston, TX.

Condensation of water-ice and other frosts on Mars should proceed by heterogeneous nucleation on dust particles because, as on Earth, the naturally occurring low degrees of atmospheric water-vapor supersaturation inhibit homogeneous nucleation. Although mineral substrates might serve to initiate condensate formation on Mars, early-formed condensates might also serve as substrates for heterogeneous nucleation of later condensates. Phase H_2O-Ic might be the best overall nucleator of other condensates so that it is important to determine which mineral substrates are the most effective nucleators of H_2O-Ic. If condensates observed at the Viking 2 landing site nucleated on red dust, implying that Fe-oxides were important nucleators, Hem and Gt would be the most competitive choices. If identity of the Fe-oxide was known, a case might have been made for the water condensate being either H_2O-Ih (favored by Hem) or H_2O-Ic (favored by Gt). Alternatively, identification of the condensate might have been used to argue for possible identification of the Fe-oxide. If the condensate was a mixture of H_2O and CO_2, a case for Gt might have been made, based on the fact that Gt favors condensation of H_2O-Ic which, in turn, favors condensation of solid CO_2.

34. Gooding, James L.: Martian Dust Particles as Condensation Nuclei: A Preliminary Assessment of Mineralogical Factors. Icarus, Vol. 66, pp. 56-74, 1986.

Condensation of frosts on Mars should depend not only on temperature and degree of vapor supersaturation but also on the nature of dust particles that would act as condensation nuclei. For a given particle

size, the favorability of a condensate nucleator is determined by (1) degree of crystallographic misfit, or disregistry (δ), between substrate and condensate, (2) chemical-bond compatibility between substrate and condensate and (3) abundance of substrate surface defects that would encourage assembly of atoms or molecules. New data on ice-forming characteristics of candidate Martian materials, obtained by differential scanning calorimetry, confirmed previous evidence for systematic variations in ice-nucleation temperature, T_{in}, among geologic materials. By considering individual types of minerals separately, factors (2) and (3) can be held relatively constant and differences in nucleation effectiveness can be estimated by computation of (1).

35. Gooding, James L.: Possible Significance of Cubic Water-Ice, H_2O-Ic, in the Atmospheric Water Cycle of Mars. Presented at the MECA Workshop on Atmospheric H_2O Observations of Earth and Mars, September 25-27, 1986, Houston, Texas.

Most discussions of water ice on Mars tacitly assume that common hexagonal ice, H_2O-Ih, is the appropriate phase. Although ice-Ih is the dominant polymorph of water-ice on Earth, a second low-pressure polymorph which crystallizes in the isometric (cubic) system, H_2O-Ic, can form in special ultracold environments. Occurrence of ice-Ic in the Mars water cycle would be significant for two reasons. First, the Ic/Ih phase transition might comprise a significant but previously unrecognized term in heat-balance equations that have been applied to evaporation or condensation in the water cycle in models for atmosphere/polar-cap or atmosphere/regolith interactions. Second, ice-Ic might possess distinctive properties as a nucleator of other condensates that could substantially affect the processing and distribution of volatiles in both the water and carbon dioxide cycles. Water vapor on Mars occurs mostly in the lower 20 km of the atmosphere where prevailing temperatures and pressures typically vary from 150 k/1 mbar at altitude to 250 K/10 mbar near the surface. Condensate clouds near and above the summits of the Tharsis volcanoes (20-27 km elevation) have been interpreted as high-altitude water-ice clouds, indicating that atmospheric condensation on Mars does, in fact, occur under the ultracold, low-pressure conditions that should favor formation of ice-Ic by the vapor-deposition mode.

36. Gooding, James L.: Water-Ice in the Martian Regolith: Experimental Investigation of Lithologic Effects. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 271-272.

New experiments were conducted to investigate the freezing and melting of water ice in a natural regolith that evolved in a Mars-like environment but without significant clay-mineral production. For silt- and sand-sized fractions, with mass ratios of water/sample = 1, the onset of freezing occurred at 266-267 K whereas the onset of melting occurred at 272-273 K. For comparison, pure water (in aluminum) undercooled to 256-257 K before onset of freezing. Therefore, the net effect of the substrate was to raise the freezing-onset temperature, relative to pure water. The temperature of melt initiation, defined as the first-inflection limit in the heat-flow curve during melting, was 271-272 K for pure water but was only 269-271 K for the water/

sample mixtures. Although melting-onset and freezing-onset tempera-
tures were approximately independent of water/sample ratio, the tem-
perature of melt initiation covaried with water/sample ratio. Even in
the absence of salts, temperatures at which freezing and melting of
water occur in the Martian regolith should not be the same as those
that apply to pure water.

37. Gooding, James L. (JSC); and Muenow, David W. (University of Hawaii):
    Martian Volatiles in Shergottite EETA79001: New Evidence From
    Oxidized Sulfur and Sulfur-Rich Aluminosilicates. Geochimica et
    Cosmochimica Acta, Vol. 50, pp. 1049-1059, 1986.
       High-vacuum pyrolysis of individual, petrologically documented chips
    of Lithology A (pyroxene-maskelynite host rock) and Lithology C (glass
    inclusion) from the same interior portion of EETA79001 produced sulfur
    in substantially different proportions of oxidized (SO_2) and reduced
    (H_2S,S_2) species. Because Lith-C contains trapped noble gases and ni-
    trogen of Martian atmospheric affinity, a logical explanation for its
    oxidized sulfur would be rock/atmosphere reactions that occurred on
    Mars prior to or during the melting event that produced Lith-C. Bulk
    elemental compositions of two varieties of sulfur-rich aluminosili-
    cates in Lith-C can be arithmetically mixed to produce a composition
    that agrees remarkably well with that of surface fines at the Viking
    landing sites, suggesting that Lith-C might actually contain relict
    grains of Martian weathering or alteration products.

38. Greeley, Ronald (Arizona State University); and Williams, Richard J.
    (JSC) editors: Space Station Planetology Experiments Workshop. NASA
    CP-2424, March, 1986, 96pp.
       A meeting of 50 planetary scientists, sponsored by Arizona State
    University and the Lunar and Planetary Institute, considered the uses
    of the Space Station to support experiments in their various disci-
    plines. Abstracts (28) present various concepts for impact and
    aeolian processes, particle formation and interaction, and other
    planetary science experiments. Summaries of the rationale, hardware
    concepts, accommodations, and recommendations are included.

39. Guimon, R. Kyle (University of Arkansas); Lofgren, Gary (JSC);
    Sears, Derek W. G. (University of Arkansas): A Study of Effect of
    Devitrification on Thermoluminescence in Type 3.4 Ordinary Chondrites.
    Presented at the 17th Lunar and Planetary Science Conference,
    March 17-21, 1986. Abstract published in Lunar and Planetary Science
    XVII, pp. 297-298.

40. Guimon, R. Kyle; Sears, Derek W. G. (University of Arkansas); Lofgren,
    Gary (JSC): Laboratory Metamorphism of a Primitive Meteorite. Pre-
    sented at the 17th Lunar and Planetary Science Conference, March 17-
    21, 1986, Houston, Texas. Abstract published in Lunar and Planetary
    Science XVII, pp. 299-300.

41. Helfert, Michael R.; and Wood, Charles A.: Shuttle Photos Show
    Madagascar Erosion. Geotimes, Vol.31, No. 3, pp. 4-5, March, 1986.

42. Henninger, Donald L. (JSC); Lagle, C. W. (Lockheed Engineering and Management Services Company); and Ming, Douglas W. (National Research Council): A Lunar Derived "Soil" For the Growth of Higher Plants. Presented at Symposium '86, September 22-24, 1986, Atlantic City, New Jersey.

Formation of a lunar regolith-derived soil substrate could support a lunar based agricultural industry. Growing higher plants in a lunar base controlled ecological life support system could remove CO_2 and add O_2 to the atmosphere, produce food, recycle waste products, contribute to a water purification system, and offer psychological support.

43. Horz, Friedich (JSC); Simon, S.B.; Papike, J. J. (South Dakota School of Mines and Technology); See, Thomas H. (Lockheed Engineering and Management Services Company): An Experimental Investigation of Agglutinate Melting Mechanisms: Shocked Mixtures of Apollo 11 and 16 Soils. Journal of Geophysical Research, Vol. 91, No. B13, E64-E74, 1986.

Tests of the fusion of the finest fraction (F^3) model for the formation of lunar agglutinate glass, in which mixtures of coarse and fine sodium and potassium feldspars were shocked, have indicated that the model is valid in principle. As a follow-up, refined experiments employed actual lunar soils (from A-11 and A-16). Other than the generation of impact melts, modal changes caused by experimental shock include destruction of pore spaces and fused-soil clasts, and conversion of plagioclase to maskelynite. From the petrographic and chemical data it appears that the impact glass formed mainly from the fine fraction and the fused soil component. The impact glasses exhibit the same chemical enrichments and depletions as the corresponding fine soil fractions, and plot on or near a mixing line between the bulk and fine fraction of the soil in which they were formed.

44. Horz, Friedrich; Cintala, Mark J. (JSC); See, Thomas H. (Lockheed Engineering and Management Services Company): Hypervelocity Particle Capture: Some Considerations Regarding Suitable Target Media. LPI Technical Report 86-05, pp. 58-60, Lunar and Planetary Institute, Houston, Texas, 1986.

Survival of unmelted impactor fragments at relatively high collision velocities has been demonstrated in the laboratory and on Solar Max thermal blankets. It thus appears possible to collect relatively unaltered hypervelocity particles in Earth orbit. Additional impact experiments are necessary to evaluate materials of ultra-low densities. Ultimately a stack of very thin foils, rather than some foam material, may also be considered and may be tailored (=L) for capture of specific impactor masses. Operationally, recovery of projectile fragments from such materials becomes a concern, because penetration paths may be tens of projectile diameters in length. Target media that may be dissolved quantitatively without adverse effects on the contemplated microanalyses appear desirable for expedient recovery of particle fragments.

45. Housen, Kevin R. (Boeing Aerospace Company); Holsapple, Keith A. (University of Washington): How Do Collisional Outcomes Depend On Size Scale? Presented at the 17th Lunar and Planetary Science Conference,

March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 262-263.

Collisional fragmentation of asteroids and satellites has been simulated in experiments in which small cubes or spheres of rock or ice are shattered during hypervelocity impacts (e.g. 1-4). Useful applications of these results require an understanding of how collisional outcomes depend on the size scale of the experiment. This is particularly important in light of the fact that observable asteroids are some 15 to 20 orders of magnitude more massive than their laboratory counterparts. The purpose here is to consider scaling laws, which help to bridge the size gap between small-scale experiments and asteroids.

46. Hubbard, W. B. (University of Arizona); Lellouch, E.; Sicardy, B. (Observatoire de Meudon); Bouchet, P. (European Southern Observatory); Vilas, Faith (JSC); and Narayan, R. (University of Arizona): Effects of Neptunian Atmospheric Waves on Central Flash and Immersion/Emersion Occultation Profiles. Presented at American Astronomical Society Division for Planetary Science Meeting, November 4-7, 1986, Paris, France.

Simultaneous observations at CTIO and ESO of the 20 August 1985 stellar occultation by Neptune, showing a central flash at both stations together with measurable intensity fluctuations through the entire occultation, yield new informaiton about the nature and origin of the well-known occultation "spikes." The two records follow parallel tracks through the Neptune shadow, separated by about 80 km and passing about 1100 km south of the shadow's geometrical center. Fluctuations seen at both stations are highly correlated (~80%) outside the shadow's mean half-intensity locus. Correlation decreases rapidly inside this locus, while mean "spike" widths systematically increase. The observed pattern can be qualitatively reproduced by a model of an oblate isothermal atmosphere with a superimposed anisotropic spectrum of random density waves. The inferred anisotropy is ~100 (radial power/transverse power). This result indicates that energy is deposited into a broad range of turbulent wavelengths in Neptune's stratosphere, with preference for small vertical wavelengths and large horizontal wavelengths.

47. Kessler, Donald J.: The Implications of Orbital Debris on the Future Space Program. Presented at the New York Academy of Sciences, April 18, 1986, New York, New York.

As a result of satellite breakups and the disintegration of spacecraft surfaces, a very large number of small particles have been detected orbiting the Earth. In certain regions of Earth orbit, the hazard to spacecraft from these particles already exceeds the hazard from natural meteoroids. New operational and engineering practices could reduce the production rate of these particles; however, new policies may soon be required which have a significant impact on the future growth of space.

48. Konradi, Andrei; Richmond, R. G.; and Hardy, A. C. (JSC); Atwell, W. (Rockwell International): Space Shuttle Dosimeters as Indicators of Long-term Inner Belt Stability. Presented at the American Geophysical

Union 1986 Fall Meeting, December 8-12, 1986, San Francisco, California.

Thermoluminescent dosimeters were carried on 20 Shuttle flights between 1983 and 1986 at a variety of orbital altitudes corresponding to the region of the atmospheric cutoff of the South Atlantic Anomaly. Shielded by the Space Shuttle structure, these dosimeters respond to any penetrating inner belt protons and galactic cosmic rays. The measured orbit averaged dose was compared to dose calculations based on radiation belt models for solar maximum and solar minimum derived from data centered around 1970 and 1964, respectively. The results show that after two solar cycles the observations agree with the predictions of the solar minimum model to better than a factor of two. This difference falls within the accuracy of the model.

49. Lellouch, E. (Observatoire de Meudon); Hubbard, W. B. (University of Arizona); Sicardy, B. (Universite de Paris); Vilas, Faith (JSC); Bouchet, P. (European Southern Observatory): Determination of Neptune's Oblateness and Methane Stratospheric Mixing Ratio. Nature, Vol. 324, p. 227, 1986.

The occultation of a star on 20 August 1985 by Neptune was observed at 2.2 μm and 0.01 s time resolution with the 1m ESO telescope and the 1.5m CTIO telescope. A highlight of these observations was the detection of a "central flash" midway between immersion and emersion. This detection provides an unexpected opportuniy to determine a value of Neptune's oblateness ϵ, and to probe the atmospheric extinction at 2.2 μm, which is related to the stratospheric methane mixing ration. We find $\epsilon = (2.08 \pm 0.19 0.18)$ 10^{-2} and assuming a 120 K stratospheric temperature, an atmospheric transmission of 0.70 ± 0.20 for an integrated column density of 1.9 km-atm. The inferred value for the CH_4 mixing ratio at 0.3 mbar is 0.6% with a factor 10 uncertainty, which may indicate supersaturation of methane in Neptune's stratosphere.

50. Lofgren, Gary: The Role of Heterogeneous Nucleation in the Development of Igneous Rock Textures. Presented at the 14th General Meeting of the International Mineralogical Association, July 13-18, 1986, Stanford, California. Published in Proceedings, pp. 158-159.

51. Lofgren, Gary (JSC); and Russell, W. J. (Lunar and Planetary Institute): Dynamic Crystallization of Chondrule Melts of Porphyritic and Radial Pyroxene Composition. Geochimica et Cosmochimica Acta, Vol. 50, pp. 1715-1726, 1986.

Dynamic crystallization experiments in which heterogeneous nucleation is an important variable have been completed on three melts of chondrule composition. Compositions were chosen to best represent chondrules with porphyritic olivine and pyroxene and radial pyroxene textures. Experimental results show that heterogeneous nucleation is nearly essential for the formation of porphyritic textures. Without preexisting nuclei, too much supercooling is established before crystallization is initiated and the textures are more likely to be dendritic or radial. In the near total absence of nuclei, radial textures can form at cooling rates as slow as 50c/hr. in this study. By varying the heterogeneous conditions and having a melt in which the appropriate phases are stable or metastable, most of the recognized chondrule textures can be produced in a single melt composition. Oli-

vine inclusions in pyroxene can form readily during an experiment from
a starting material which did not initially contain olivine crystals.
Thus care must be taken in the assumption that olivine inclusions in
pyroxene represent preexisting crystals.

52. Mackinnon, Ian D. R. (University of New Mexico); and McKay, David S.
(JSC): Refinements and Developments on the Stratospheric Dust Data-
base and Classification Scheme. Presented at the 17th Lunar and Plan-
etary Science Conference, March 17-21, 1986, Houston, Texas. Abstract
published in Lunar and Planetary Science XVII, pp. 510-511.

53. McCord, Thomas B. (University of Hawaii); Vilas, Faith (JSC): Reflect-
ance Spectrophotometry of Mercury: Implications for the Surface Com-
position. Presented at the Mercury Conference, August 6-9, 1986,
Tucson, Arizona.

Reflectance spectra of Mercury have been obtained periodically from
1963 through 1984. Since 1969, these observations were made in an ef-
fort to learn about the surface mineralogical composition of Mercury,
and, by extension, surface and internal processes which have affected
the planet's evolution. Using the phases of the planet around maximum
elongations, Mercury's 6.1385 deg/day rotational rate, and bidired-
tional reflectance spectroscopy theory, some spatial resolution across
the planet has been obtained. Ambiguities exist among recent, high
quality spetra covering terrain consisting of 50% intercrater plains
and 50% Caloris Basin with the encompassing smooth plains. A very
shallow absorption feature, which has been attributed to Fe^{2+} in or-
thopyroxenes, is evident in two spectra but noticeably absent in a
third. This difference cannot be explained by reflected light from
different terrain.

54. McCoy, James E.: Plasma Motor/Generator Proof of Function Experiment.
Presented at the NASA/AIAA/PSN International Conference on Tethers in
Space, September 17-19, 1986, Arlington, Virginia.

The Plasma Motor/Generator-Proof (PMG/POF) of Function Experiment is
a low cost Payload of Opportunity for flight on the Shuttle Orbiter
using the Hitchhiker-G carrier. The objective of this experiment is
to provide a credible engineering verification of the key physical
processes identified as crucial to the performance of Plasma
Motor/Generator (PMG) tether systems by flying a PMG/POF "non-tether"
experiment. The experiment deploys a far end package (FEP) containing
a hollow cathode system, connected to another hollow cathode system at
the Orbiter end by a #32 AWG umbilical wire. Adequate induced voltage
and separation from spacecraft wake effects is achieved by the 200
meter wire length, without having to deal with tether stabilization
and retrieval problems, for demonstration of the hollow cathode plasma
coupling. The deployed wire and 25 kg FEP are jettisoned at the
completion of the experiment. The results obtained from initial
flights now scheduled for HHG-2 and HHG-3 will also provide a basis
for planning larger scale investigations using the TSS system and
expanded PMG/POF type experiments.

55. McCoy, James E.: Plasma Motor/Generator Reference System Designs for
Power and Propulsion. Presented at the NASA/AIAA/PSN International
Conference on Tethers in Space, September 17-19, 1986, Arlington,

Virginia.

NASA-JSC has defined four PMG reference systems to provide a standard basis for comparison to use in study and analysis of future propulsion and power applications. Sized for nominal operation at 2 kW, 20 kW, 200 kW, and 1 Megawatt respectively, they are a hollow cathode based version of the electrodynamic tether concept, which we identify by the terminology "Plasma Motor-Generator" (PMG). The PMG reference systems are equally applicable to use as electric generators to provide power to a spacecraft or as electric motors (nominal thrust ratings of .25, 2.5, 25 and 125 Newtons respectively) using power from the spacecraft. After comparing solar array and fuel cells with electrodynamic tethers using passive metal "balloons," electron guns, and/ or various plasma sources, the studies at JSC settled on the PMG system using a short massive tether of aluminum wire and teflon insulation. Operating at relatively high current and low voltage, the PMG avoids requirements for technology advances to handle very high voltages. All four reference systems employ passive, IxB phasing of magnetic reaction forces for control of tether dynamics, and DC impedance matching for tether current/power control. If a specific mission results in dynamic disturbances beyond the stability limits of the 10 km massive tether without satellite or tether reel, a 10-100 km low mass ballast tether (or "space anchor") with a small anchor mass would be used. In no case does active "tether reeling" appear to be required for any of the presently recommended applications.

56. McDowell, A. F. (Lunar and Planetary Institute); and Nyquist, Laurence E. (JSC): Cosmogenic Nuclide Production in Ellipsoidal Meteoroids. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 528-529.

57. McKay David S.; Bogard, Donald D.; Morris, Richard V. (JSC); Korotev, R. L. (Washington University); Johnson, P. (Northrop Services); and Wentworth, S. J. (Lockheed Engineering and Management Services Company): Apollo 16 Regolith Breccias: Characterization and Evidence for Early Formation in the Mega-Regolith. Journal of Geophysical Research, Vol. 91, No. B4, pp. D277-D303, March 30, 1986.

The Apollo 16 regolith breccias resemble the soils in grain-size distribution and in the relative proportions of major petrological components, except agglutinates. Many of the breccias are compositionally different from the Apollo 16 soils in that they lack an important mafic component present in the soils. Although some groupings occur, the petrologic and chemical compositions of the regolith breccias do not correlate with the station location of the samples. All but one of the breccias show some evidence of irradiation at the lunar surface. We conclude that most of the Apollo 16 regolith breccias were not formed from any known Apollo 16 soil. They appear to be well-comminuted material that contains ancient regolith developed during the late stage heavy bombardment of the moon when large impacts were much more common relative to small impacts so that regolith did not have time to significantly mature before being diluted by fresh ejecta and buried.

58. McKay, David S. (JSC); Wentworth, S. J. (Lockheed Engineering and Man-

agement Services Company): Ancient Lunar Glasses as Clues to the Early Meteoroid Complex. Presented at the 49th Annual Meeting of the Meteoritical Society, September 22-25, 1986, New York, New York.

Glasses are a ubiquitous component of regolith breccias. These glasses include ropy, clastic, and quenched crystallized types as well as homogeneous glasses. Several lines of evidence suggest that many, and in some cases most, of these glasses were not made from local regolith by small scale reworking processes. This evidence includes high relative abundances of these glass types compared to agglutinates in many regolith breccias and presence of these glass types in regolith breccias having very low FMR maturity (an indication of lunar surface reworking by small impacts) interpretations that ropy glass types are mainly derived from large impacts and the high abundances of glasses of non-local composition in some regolith breccias. Specifically, up to 80% of non-mare glasses in some Apollo 15 regolith breccias are KREEP-rich. Although KREEP rocks are inferred to be present in the Apennine Bench formation and in other regions close to the Apollo 15 site (3), the KREEP-rich glasses were not produced from any combination of local mare basalts or local soils of the compositions sampled at the Apennine front. An attempt to systematically group these glasses from regolith breccias by both compositional groupings and age clusters might provide a record of the composition and frequency of major impactors in the earth-moon system over time. This record could be compared with the terrestrial impact record to further explore whether such impacts might be episodic. This comparison might be particularly profitable for glasses from younger regolith breccias because these impact glasses may overlap the time span best defined in the terrestrial record.

59. McKay, Gordon A.: Crystal/Liquid Partitioning of REE in Basaltic Systems: Extreme Fractionation of REE in Olivine. Geochimica et Cosmochimica Acta, vol. 50, pp. 69-79, 1986.

60. McKay, Gordon A. (JSC): REE Partitioning and the Shergotty Parent Melt: Evidence for Complex Petrogenesis and against Metasomatic Alteration. Presented at the 11th Symposium on Antarctic Meteorites, March 25-27, 1986, Tokyo, Japan.

The shergottites are a group of igneous-textured meteorites which may be from Mars. Despite extensive study by the Shergotty Consortium, chronology and petrogenesis of the Shergotty meteorite remain controversial. One aspect of this controversy concerns whether Shergotty has undergone metasomatic alteration. Another concerns the Sm/Nd ratio of the Shergotty parent melt (SPM), and the resulting implications for the complexity of melt generation processes. While Shergotty's bulk Sm/Nd is greater than chondritic, the source region (SR) is constrained by isotopic systematics to have Sm/Nd less than chondritic. If $Sm/Nd_{SPM} \angle Sm/Nd_{SR}$, this melt could have been generated by simple processes such as equilibrium partial melting of common mafic mineral assemblages. However, if $SM/Nd_{SPM} > SM/Nd_{SR}$, more complex processes (e.g., batch melting) are required. SM and Nd D's for Shergotty zoned augite rims do not differ markedly from those for magnesian cores of similar WO. Factors in addition to PX Fe/Mg are responsible for the apparent correlation with pheno/matrix D's. Similarity of D's for rims and cores supports our previous estimate of

the REE content of the Shergotty parent melt. Agreement between SPM Sm and Nd contents calculated from mineral separates and from bulk sample argues against metasomatic alteration. Extreme LREE enrichment in Fe-rich PX separates is <u>NOT</u> intrinsic to PX.

61. McKay, Gordon A. (JSC); Le, L.; Wagstaff, J.; and Yang S.-R. (Lockheed Engineering and Management services Company): Whitlockite/melt Partitioning and Shergotty Chronology. Presented at the 49th Meteoritical Society Meeting, September 1986, New York, New York.

62. McKay, Gordon A.; Wagstaff, J.; and Le, L. (Lockheed Engineering and Management Services Company): Pyroxene Distribution Coefficients, the Shergotty Parent Melt, and Metasomatic Alteration. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 537-538.

63. McKay, Gordon A. (JSC); Wagstaff, J.; and Yang, S.-R. (Lockheed Engineering and Management Services Company): Clinopyroxene REE Distribution Coefficients for Shergottites: The REE content of the Shergotty Melt. <u>Geochimica et Cosmochimica Acta</u>, Vol. 50, pp. 927-937, June 1986.

   REE distribution coefficients were measured between synthetic pyroxenes and melts similar in composition to the inferred Shergotty intercumulus liquid, by <u>in situ</u> analysis with the electron microprobe, using samples doped to per cent concentration levels. These coefficients exhibit a strong positive correlation with pyroxene wollastonite content. Recommended values for augites similar in composition to the Shergotty cumulus augite cores ($Wo_{32}En_{48}$) are D(La)=0.023, D(Ce)=0.039, D(Nd)=0.10, D(Sm)=0.17, D(Eu)=0.16, D (Gd)=0.20, D(Yb)32=0.29, and D(Lu) =0.30. Recommended values for pigeonites similar in composition to the Shergotty cumulus pigeonite cores ($Wo_{12}En_{58}$) are D(La) =0.002, D(Ce)=0 .004, D(Nd)=0.019, D(Sm)=0.031, D(Yb)=0.13, and D(Lu) =0.13. These values resemble distribution coefficients measured for terrestrial basalts of higher Mg/Fe than the Shergotty melt, rather than those of more evolved siliceous rocks of similar Mg/Fe to the Shergotty melt. Thus it appears that Mg/Fe is considerably less important than other factors in determining distribution coefficient values for pyroxenes.

   REE abundances were computed for the Shergotty intercumulus melt using distribution coefficients measured for the natural phase compositions. These computed abundances display LREE depletion. Such LREE-depleted abundance patterns cannot be generated by simple partial melting of a mafic mineral assemblage having the LREE-enriched patterns required for a two-stage Sm-Nd evolution history. This result implies that either (1) the melting process was complex (e.g., continuous melting), (2) the source region had a more complex history than that of the simple 2-stage model, or (3) Shergotty does not satisfy the closed-system assumption of the calculation, and has suffered post-magmatic LREE-enrichment.

64. Mendell, Wendell W.: Colonization of the Solar System. Presented at the Conference on "The Agenda: Possibilities, Groups, and Tasks," October 17-20, 1986, Aix-en-Provence, France.

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Permanent bases on the Moon and Mars are the first steps in colonization of the solar system. Studies have established that the key technologies for accomplishing these programs are power generation, propulsion, and self-sufficient life support. The greatest technological uncertainties associated with long range planning lie with the life support systems, human physiological reactions to long duration space travel, and psychological and social responses to isolated and confined habitation on planetary surfaces. Projections based on solution of technical problems and only modest investment in space activities predict a Mars base within 50 years. At the present time, the timetable for extraterrestrial development is constrained by social issues rather than purely technical ones. Only large social groups (such as nations) can garner the resources necessary to move people into space. However, given the geometric character of technological development, the space-based technology of the future may place such resources of power, propulsion, and manufacturing within the reach of smaller groups. Under such conditions space colonization will grow faster than anticipated in the same way the New World grew explosively once its resources were within the reach of entrepreneurs.

65. Mendell, Wendell W.: Lunar Bases and Space Activities of the 21st Century. Presented at the AIAA Conference on Aerospace Sciences, January 8, 1986, Reno, Nevada; and at the 22nd International Horticultural Congress, University of California - Davis, August 11, 1986, Davis, California.

By the turn of the Century, passenger traffic to low Earth orbit (LEO) will increase on the Space Shuttle, or its successor, as well as on planned Soviet and European vehicles. In addition, the U.S. and its international partners plan to construct in LEO a permanently manned space station. Berthed at the space station will be orbital transfer vehicles, reusable spacecraft capable of taking payloads to geosynchronous orbit and other destinations beyond Earth's radiation belts. These space transportation elements could take humans and cargo to the Moon routinely. Although not now part of NASA's plans, manned lunar landings will be possible early in the 21st Century. As human activity in space becomes commonplace, a base on the Moon will become an issue of space policy. Informal studies of such an enterprise have identified the near term roles of politics, economics, and science in establishing and sustaining a permanent lunar surface facility. In the long term, a lunar experience can be the beginings of settlement of the solar system. However, the limiting factor in such visionary scenarios is the performance of biological systems rather than transportation technology. The major challenge to sustaining a permanent lunar base is closure of a life support system based on ecological principles rather than chemical processing. Thus, the next steps in space should provide extraordinary new research opportunities for agriculture in a unique environment.

66. Mendell, Wendell W.; and Duke, Michael B.: Economic Selenology. Presented at the American Association of Petroleum Geologists Meeting, June 17, 1986, Atlanta, Georgia.

In 15 years, by the year 2000, the Space Transportation System will include reusable upper stages delivering payloads from the Space Station to destinations such as geosynchronous orbit (GEO) and lunar or-

bit. The principles being expressed in space policy predict that a permanent lunar surface base will then be on the agenda. Although commonly viewed as an exercise in technology, human occupation of the Moon has implications for science, law, domestic politics, international relations, and the economics of space development. Economic issues take on particular importance for strategic planning. Long term continuous presence cannot become a reality unless political drivers are superseded by economic ones. Current models of space activities indicate potential markets in space for lunar resources in the form of propellant, shielding, and structural material. More complete cost and market analysis requires research on process technologies adapted to the lunar environment and on geological inventory of the lunar resource base.

67. Meyer, Charles (JSC); Williams, I. S.; and Compston, W. (Australian National University): Direct Evidence of Ancient Lunar Granite. Presented at the 6th International Conference on Geochronology, Cosmochronology, and Isotope Geology, June 30 - July 4, 1986, Cambridge, England.

The SHRIMP ion microprobe at the ANU was used to determine Pb/Pb, U/Pb and Th/Pb ages of small zircons intergrown in six clasts of lunar granite found in thin sections of Apollo 14, 15, and 17 breccias. Four small clasts with a variety of granitic textures and mineralogies have zircons with concordant ages. Two granitic clasts in breccia 15405 include small euhedral zircons which gave concordia intercepts of about 4.33 BY with evidence of Pb loss at the time of breccia formation about 1.3 BY. Both the 14303,209 granite and 15405 QMD clasts have been measured to have the REE pattern of lunar KREEP. This is the first direct evidence that some lunar granite crystallized during the solidification of the global lunar magma ocean. Previous investigations have determined that younger lunar granites have low initial Sr ratios and cannot simply be remelted ancient granite but may have instead formed in layered intrusions in the lunar crust.

68. Ming, Douglas W. (JSC); Dixon, Joe B. (Texas A&M University): Zeolites: Recent Developments in Soil Mineralogy. Presented at the Proceedings of the 13th International Soil Science Society Congress, August, 1986, Hamburg, West Germany.

The special properties of zeolites have prompted their use in a variety of agricultural processes. These hydrated aluminosilicates of alkali and alkaline earth cations have been recognized (1) to form in saline, alkaline soils; (2) to occur as residual phases in soils with zeolite-rich parent rocks; and (3) to occur as phases introduced in soils by eolian additions and fluvial deposition. There are over 40 naturally occurring zeolites; however, only about 9 zeolite types have been recognized to occur in soils, including clinoptilolite, analcime, chabazite, heulandite, mordenite, phillipsite, natrolite, stilbite, and gismondine. Clinoptilolite is the most abundant zeolite in soils. Several analytical methods have been used to identify zeolites in soils, including x-ray diffraction (XRD), scanning electron microscopy (SEM), electron microprobe analysis, transmission electron microscopy (TEM), infrared analysis, and cation exchange capacity (CEC). Quantities of zeolites have been estimated in soils by semiquantitative XRD analysis and by chemical measurements using a CEC method. For routine

chemical and mineralogical analyses, it is possible to separate the zeolite from soils of various mineralogies by particle size fractionation and heavy liquid separations. Special precautions should be exercised when treating soils with chemical dispersants before mineralogical analyses. Zeolites with high Si/Al atomic ratios (e.g., clinoptilolite) can withstand chemical dispersion (e.g., IN NaOAc buffered to pH=5, 30% H_2O_2, and dithionite-citrate-bicarbonate); however, zeolites with low Si/Al atomic ratios (e.g., analcime) tend to dissolve during acid pretreatments.

69. Mittlefehldt, David W. (National Research Council): Alkali Element Abundances in Achondrites and Volatile Loss From Achondrite Parent Bodies. Presented at the 49th Annual Meeting of the Meteoritical Society, September 22-25, 1986, New York, New York.

I have attempted to set constraints on the causes of extreme volatile depletion by examining a large body of geochemical data on the basaltic achondrites. The data considered here include analyses of whole rock eucrites and diogenites and igneous lithic clasts from eucrites, diogenites, polymict eucrites, howardites and mesosiderites. The parent body of the basaltic achondrites appears to have initially contained alkali element (and presumably other volatile element) abundances comparable to those in CO and CV chondrites, and perhaps higher. Magmatic processes on the basaltic achondrite parent body resulted in >90% loss of the volatile alkali element inventory from the parent body. The positive correlations observed between e.g. Rb and Rb/AHIR (Average Highly Incompatible Refractory) elements in basaltic lithologies are the result of volatilization from the basaltic magmas near the surface of the parent body.

70. Mittlefehldt, David W. (National Research Council); Bansal, B. M.; Shih, C.-Y.; Wiesmann, H. (Lockheed Engineering and Management Services Company); Nyquist, L. E. (JSC): Petrology, Chronology and Chemistry of Basaltic Clasts From Mesosiderites. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 553-554.

Petrologic and chronologic studies of basaltic clasts in Meosiderites have been initiated in order to determine the petrologic evolution of their parent body. Patwar RV-02 is a two-pyroxene (pigeonite-augite) basalt in which augite is a late magmatic phase. This clast has suffered shock metamorphism that has modified the original magmatic texture. Pyroxene composition data show that FeO reduction processes occurred during crystallization from the magma. Mount Padbury RV-05 is a one-pyroxene (pigeonite) basalt that also underwent shock metamorphism. The pyroxene compositions give no evidence for magmatic FeO reduction processes. We believe that from the melt by increasing the Ca/(Ca+Fe+Mg+Mn) ratio of the melt. Preliminary Rb-Sr results on Patwar RV-02 show that the Rb-Sr system is disturbed, and yield an upper limit for the age of shock metamorphism of 3.6 Ga.

71. Mittlefehldt, David W. (National Research Council); Bansal, B. M.; Shih, C. -Y.; Wiesmann, H. (Lockheed Engineering and Management Services Company); Nyquist, L. E. (JSC): Petrogenesis of Type 1A Meso-

siderite Silicates. Presented at the 49th Annual Meeting of the Meteoritical Society, September 22-25, 1986, New York, New York.

    We are continuing our chronologic and petrologic study of basalts and gabbros from mesosiderites. Vaca Muerta RC-07 is a coarse-grained gabbro clast with high tridymite and merrillite abundances. Pyroxene in this clast contains abundant inclusions of rounded plagioclase, a feature not observed in the gabbroic eucrite Moore County. RC-07 pyroxenes show a trend of decreasing Fe/Mn with Fe/Mg caused by FeO reduction in the magma as previously noted for Patwar RV-02. Preliminary RB-Sr results for Vaca Muerta RC-07 show that the whole rock lies on a eucrite reference isochron of 4.56 Ga age. Basalt clast RV-05 from Mount Padbury yields an isochron age of metamorphism of 0.92 GA, but the data indicate that the Rb-SR system was not completely reset at this time. Many of the petrological and chemical features of mesosiderite basalts and gabbros suggest that they may have been formed by impact melting processes. We are evaluating this possibility.

72. Miyamoto, Masamichi; Meguro-ku, Komaba (University of Tokyo); McKay, David S.; Lofgren, Gary; and Duke, Michael B. (JSC): Melting Experiments on a LL Chondrite. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 563-564.

73. Mohler, Robert R. J. (Lockheed Engineering and Management Services Company); Hallum, Cecil R. (University of Houston at Clear Lake): Analysis of Drought Environments Using Multi-Sensor Data. <u>Forum of the Association for Arid Lands Studies</u>, Vol. 2, pp. 73-78, April, 1986.

74. Mohler, Robert R. J.; Palmer, Wesley T. and Baker, Thomas C. (Lockheed Engineering and Management Services Company); and Bizzell, Robert M. (JSC): An Automatic Procedure for Estimating Spring Small Grains Acreage From Landsat Data. <u>Professional Geographics</u>, Vol. 38, No. 4, pp. 375-382, November, 1986.

75. Mohler, Robert R. J.; Trenchard, Michael H. (Lockheed Engineering and Management Services Company); Wells, Gordon L. (Lunar and Planetary Institute); and Hallum, Cecil R. (University of Houston-Clear Lake): Monitoring Vegetation of Drought Environments. <u>Bioscience</u>, Vol. 36, No. 7, pp. 478-483, July/August, 1986.

76. Morris, Richard V. (JSC); and Lauer, Howard V., Jr. (Lockheed Engineering and Management Services Company): Evidence for Hematite on Mars: Spectral Properties of Ferric Iron Phases in Annealed, Al-Rich Precipitates of Fe-Al Sulfate Salt Solutions. Presented at the 17th Lunar Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 573-574.

77. Morris, Richard V. (JSC); Lauer, Howard V., Jr. (Lockheed Engineering and Management Services Company); Agresti, David G. ; and Newcomb, Jeffery A. (University of Alabama): Spectral Properties of Dust Produced in the Dry Valleys of Antarctica: A Martian Analogue? Presented at the Dust on Mars Workshop, February 24-25, 1986, Tempe, Arizona.

The Dry Valleys are a deglaciated set of valleys located in southern Victoria Land, Antarctica. Physical weathering processes dominate there because the low temperatures and paucity of liquid water limit chemical weathering and also participation by biological activity. Chemical weathering does occur, although at very slow rates. Basically, it is characterized by the decomposition of primary silicate minerals into clay minerals and amorphous to crystalline ferric oxides. The cold, dry climate of the Dry Valleys is probably the best terrestrial approximation to the climate of contemporary Mars. It is possible that weathering processes dominant in the Dry Valleys are also active on the martian surface. We are studying the spectral manifestations of weathering in Dry Valley soils as an analogue for interpreting martian spectral data in terms of primary and secondary mineralogies.

78. Morris, Richard V. (JSC); See, Thomas H. (Lockheed Engineering and Management Services Company); Horz, Friedrich (JSC): Composition of the Cayley Formation at Apollo 16 as Inferred from Impact Melt Splashes. Journal of Geophysical Research, Vol. 91, No. B13, pp. E21-E42, 1986.

79. Morrison, Donald A.; Phinney, William C. (JSC); and Maczuga, David E. (Lockheed Engineering and Management Services Company): Layering in the Mulcahy Lake Gabbro. Presented at the Geological Association of Canada Annual Meeting, May 19, 1986, Ottawa, Canada.

The Mulcahy lake gabbro is a 6 km thick Archean layered intrusion consisting of lower, middle, upper and marginal zones, each with iron-enrichment fractionation trends interrupted by cycles of replenishment and mixing. Plagioclase, cpx, opx, and rare olivine are cumulus phases. Magnetite forms thin cumulates in highly evolved compositions. Hornblende invariably is an intercumulus phase. The parent liquid was multiply saturated and the residual liquids increased in density during fractionation and layer development.

80. Morrison, Donald A.; Phinney, William C. (JSC); and Maczuga, David E. (Lockheed Engineering and Management Services Company): A Link Between the Bird River Sill and Nearby Basalts. Presented at the Geological Association of Canada Annual Meeting May 19, 1986, Ottawa, Canada.

The Bird River sill and apparently associated basaltic flows and hypa-byssal units are representatives of a class of Archean rocks typified by the presence of equant plagioclase megacrysts of An85+/-5. Equant plagioclase megacrysts occur sparsely in discrete horizons in the lower anorthositic and upper anorthositic units of the sill. Megacrysts in the upper unit are An86+/-1 with sodic rims. Matrix plagioclase is An86 (cores) to <An71 (rims). Megacrysts in the lower anorthositic unit are An88-81 and matrix laths are An88-81 (cores) to An50 (rims), although one horizon has An35 to 32. These lower units occur a few meters above the contact with the sill's basal ultramafic unit which has relict olivine of Fo74. Compositionally and texturally identical megacrysts occur in volcanics and hypabyssal rocks exposed to the north of the sill proper. Rare earth abundances in megacrysts and flows indicate that the flows could be parental to the megacrysts. The MgO/FeO ratios of the flows are compatible with the relic olivine observed at the top of the ultramafic unit. Experimental crystalli-

zation (one atm, FMQ) of representative flow compositions shows that plagioclase of megacryst composition is on the liquidus for about 25 C. before cpx and then olivine appear. An85 plagioclase is neutrally bouyant or may float in the multiply saturated liquid. These observations indicate that the basalts could represent a liquid parental to the sill.

81. Morrison, Donald A.; Phinney, William C. (JSC); and Maczuga, David E. (Lockheed Engineering and Mangement Services Company): Origin of Archean Anorthosites. Presented at the American Geophysical Union Fall Meeting, December 8, 1986, San Francisco, California. Abstract published in EOS, Vol. 67, p. 1265, 1987.

Archean anorthosites and related plagioclase megacryst-bearing volcanics and hypabyssal rocks form a small but important part of Archean terrains. Equant, unzoned plagioclase megacrysts are >An80 and constant An suggests a small temperature interval. The anorthosite at Bad Vermilion Lake, Ontario (92.45W, 44.40N), is stratified, consisting of units distinguished by variatons in megacryst size frequency distributions. Sorting, gradations from well sorted to unsorted units, and mixing of size variants suggest that flow was important in the stratification process. Significant adcumulate growth of plagioclase and mafics occurred. The parent liquid is a high iron tholeiite in which An80 plagioclase floats or is neutrally buoyant at ambient conditions.

82. Murali, A. V.(National Research Council); Zolensky, Michael E.; Blanchard, Douglas (JSC); and Sommer, M. A. (Lockheed Engineering and Management Services Company): Tektite-like Bodies at the Lonar Crater, India: Implications for the Origin of Tektites. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Published in Journal of Geophysical Research, Vol. 92, 1987.

Homogeneous, dense (both irregular and splash form) glass bodies with high silica contents (~67% SiO_2) occur in the vicinity of Lonar crater, India. Petrographic and chemical criteria clearly indicate that these are not volcanic in origin and are quite similar to the tektites reported in the literature. The tektite-like bodies at Lonar crater are unique in that they occur in an essentially basaltic terrain providing an opportunity to study their formation. Geochemical data suggests that these tektite-like bodies are the impact melt products of 2/3 local basalt component and 1/3 intertrappean sediment (chert) occurring locally. Strong terrestial geochemical signatures reflecting the target rock patterns and abundance ratios clearly support their terrestrial origin due to meteorite impact, as has been suggested by earlier workers.

83. Nyquist, Laurence E. (JSC); Wiesmann, H.; Shih, C.-Y.; and Bansal, B. (Lockheed Engineering and Management Services Company): Sr Isotopic Systematics of EETA 79001 Glass. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 624-625.

84. Petersen, Jon S. (Aarhus University, Denmark); and Lofgren, Gary E.

(JSC): Lamellar and Patchy Intergrowths in Feldspars: Experimental Crystallization of Eutectic Silicates. <u>American Mineralogist</u>, Vol. 71, pp. 343-355, 1986.

Coupled and noncoupled eutectic feldspar intergrowths have been produced by dynamic crystallization experiments in the ternary feldspar-water system. Fractionation during plagioclase crystallization in nearly all compositions examined results in eutectic growth when a solute-enriched boundary layer becomes supersaturated with K-feldspar. The growth rate of the eutectic product generally exceeds that of monophase growth by a factor of 10 or higher and is an effective means of reducing thermal supercooling. Coupled intergrowths have lamellar structures that are normal to a planar, nonfaceted, solid-liquid interface. Uncoupled eutectic growth occurs in the more K-rich melts. The melt-grown composites have textures strikingly similar to feldspar intergrowths found in cumulus feldspars of the Larvikite monzonite suite in the Oslo igneous province, and this similarity suggests that eutectic growth from near-cotectic melts may account for certain coarse feldspar intergrowths.

85. Phinney, William C. (JSC): From What and How Fast Does Crust Form? Summary of "The Dynamic Earth" Session of the 17th Lunar and Planetary Science Conference. <u>Geotimes</u>, Vol. 31, No. 6, pp. 13-14, June 1986.

A broad-ranging session on "The Dynamic Earth" included papers on evolution of the atmosphere, crust, mantle, and core as well as on igneous processes, tectonics, and questions about the evidence for terrestrial impacts.

86. Phinney, William C.; Morrison, Donald A. (JSC); and Maczuga, David E. (Lockheed Engineering and Management Services Company): Archean Megacrystic Plagioclase Units and the Tectonic Setting of Greenstones. LPI Technical Report 86-10, pp. 174-176, Lunar and Planetary Institute, Houston, Texas, 1986.

87. Phinney, William C.; Morrison, Donald A. (JSC); and Maczuga, David E. (Lockheed Engineering and Management Services Company): Multiple Sources for Basaltic Archean Melts. Presented at the American Geophysical Union Spring Meeting, May 19-22, 1986, Baltimore, Maryland. Abstract published in <u>EOS</u>, Vol. 67, p. 384, 1987.

Large (up to 20 cm), equidimensional, highly calcic (An$_{80-90}$) plagioclase megacrysts occur in all Archean cratons both as anorthositic complexes and in basaltic sills, dikes, and flows. The megacrysts occur in two distinct environments: (1) extensive, subparallel dikeswarms that crosscut huge areas of gneisses and greenstones, and (2) flows or small intrusions in greenstone belts. The former indicate large stable continental terrains whereas the latter suggest oceanic terrains. Both require large volumes of melt for long periods of time under huge areas of both continental and oceanic Archean crust. Rare earth element analyses of the matrices and separated plagioclase combined with experimentally determined distribution coefficients predict both tholeiitic and alkalic basalts as the parent melts.

88. Potter, A. E. (JSC); and Morgan, T. H. (Southwestern University): Fur-

ther Observations of Sodium on Mercury. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published <u>Lunar and Planetary Science XVII</u>, p. 676.

Following the initial discovery of sodium vapor in the atmosphere of Mercury, additional observations have been made, using both the University of Texas McDonald Observatory 2.4 meter telescope and the Mc-Math Solar Telescope at KPNO. The sodium density appears to fluctuate, with a maximum density observed during July 1985. A temperature estimate was made from high resolution measurements of the line profile, with the result that the apparent translational temperature is approximately 500 K. Spatial distribution was measured using the Mc-Math solar telescope main spectrograph coupled to a CID image detector. The sodium atmosphere appears to be about 20% larger than the planet measured along the north/south polar line. There was no evidence for a "tail," as was suggested by earlier spectroscopic measurements. The sodium is thought to keep a steady-state balance between supply and loss. The main source is probably meteoritic infall. It is lost by ionization and trapping in the solar wind, and by radiation pressure during times when the radial velocity of Mercury relative to the Sun is large.

89. Potter, A. E. (JSC); and Morgan, T. H. (National Research Council): Observed Variations in the Column Density of Sodium. Presented at the Mercury Conference, August 6-9, 1986, Tucson, Arizona.

Observations of the sodium D emission from Mercury at six different apparitions have been obtained and reduced. These data indicate that the column density of sodium in the atmosphere of Mercury is not the constant. All of the physical processes which have been proposed to control the column density of sodium in the atmosphere of Mercury depend on the radius of the orbit or the radial velocity along the line of sight to the Sun, or both. The observed column density appears to decrease with increasing radial velocity, which is consistent with a sodium loss process modulated by radiation pressure. However, an atom of sodium can be removed by radiation pressure only if the atom initially has a large velocity (1 to 2 km/s) or is initially at great height above the planet. Our observations indicate that the bulk of the sodium in the atmosphere is close to the planet (, 100 km.) and in approximate thermal equilibrium (characterized by a temperature of 500 K) with the sunlit surface. The implications of this observation for candidate source mechanisms for sodium are discussed.

90. Potter, A. E. (JSC); and Morgan, T. H. (Southwestern University): Potassium in Atmosphere of Mercury. <u>Icarus</u>, Vol. 67, pp. 336-340, 1986 Ithaca, New York.

The discovery of potassium in the atmosphere of Mercury is reported. The average column density is approximately 10^9 atoms/cm^2 column, which is about 0.5 percent of the average sodium column density.

91. Potter, A. E. ; and Morgan, T. H. (National Research Council): Variations of Sodium and Potassium in the Atmosphere of Mercury. Presented at the 18th Annual Meeting of the AAS Division for Planetary Sciences, November 4-7, 1986, Paris, France.

The sodium D line emmision from Mercury has been observed at seven

different apparitions. The column abundance of sodium vapor, estimated from the ratio of the two D lines, was not constant, but varied with time and with position on the planet. The disc-averaged sodium abundance appeared to decrease with increasing solar radiation pressure, which implies that radiation pressure plays a role in the sodium atmosphere. The north-south distribution of sodium differed in the two spatially-resolved observations completed to date. Potassium emission from Mercury was measured at two apparitions. The disc-averaged sodium/potassium ratio was approximately 80, which is much greater than the cosmic abundance ratio. The north-south distribution of potassium on the planet was found to be different from that for sodium.

92. Rietmeijer, Frans J. M. (Lockheed Engineering and Management Services Company): The Importance of Capturing Unmodified Chondritic Porous Micrometeorites on the Space Station. Published in Horz, Friedrich, editor: <u>Trajectory Determinations and Collection of Micrometeoroids on the Space Station: Report of the Workshop on Micrometeorite Capture Experiments</u>, LPI Technical Report 86-05, pp. 80-82, Lunar and Planetary Institute, Houston, Texas.

Capture of micrometeoroids using impactors in low-Earth orbit may destroy their chemical, mineralogical, and structural properties. A survey of chondritic porous micrometeorites lists their properties that may provide information on formation and evolution of comets and asteroids. These requirements constrain capture of micrometeroids on the Space Station.

93. Rietmeijer, Frans J. M. (Lockheed Engineering and Management Services Company): Olivines and Iron-Sulfides in Chondritic Porous Aggregate U2015*B Formed at Low-Temperature During Annealing of Amorphous Precursor Materials. Presented at the 49th Annual Meeting of the Meteoritical Society, September 22-25, 1986, New York, New York. Published in <u>Meteoritics</u>, Vol. 21, pp. 492-493, 1986.

Analytical electron microscopy of the anhydrous mineralogy of an interplanetary dust particle shows that the chemical composition of constituent olivines and iron-sulfides, as well as the structural properties of the particle, are consistent with low-temperature annealing of an amorphous presolar precursor.

94. Rietmeijer, Frans J. M. (Lockheed Engineering and Management Services Company): Silica-Rich Glass and Trydimite in a Chondritic Porous Aggregate: Evidence for Stratospheric Contamination of Interplanetary Dust Particles. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 708-709.

Analytical electron microscopy of an interplanetary dust particle collected in the Earth's stratosphere showed the presence of unusual silica-rich particles. Their chemical, crystallographical and morphological properties are consistent with a volcanic origin. It is suggested that during prolonged periods of global volcanism stratospheric collections of micrometeorites may become contaminated with small-sized volcanic particles.

95. Rietmeijer, Frans J. M. (Lockheed Engineering and Management Services

Company): Study of Micrometeorites and Space-Age Debris Offers a Challenge. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Published in Geotimes, Vol. 31, pp. 21-22, June, 1986.

Micrometeorites collected in the Earth's stratosphere and by Earth-orbiting satellites are currently investigated using a wide variety of micro-analytical techniques. These studies provide a wealth of data on small bodies in our solar system, such as comets and asteroids.

96. Rietmeijer, Frans J. M. (Lockheed Engineering and Management Services Company); Nuth, Joseph A. (NASA Headquarters); MacKinnon, Ian D. (University of New Mexico): Analytical Electron Microscopy of Mg-SiO Smokes: A Comparison with Infrared and X-Ray Diffraction Studies. Icarus, Vol. 66, No. 2, Article 3543, May 1986.

Experimentally obtained Mg-SiO smokes were studied by analytical electron microscopy (AEM) using samples that had been previously characterised by repeated IR-spectroscopy. AEM shows that unannealed smokes contain some degree of (micro-) crystallinity which increases with increased annealing for up to 30 hours. An SiO_2 polymorph (tridymite), MgO as well as Si and Mg metal may form contemporaneously as a result of growth of forsterite (Mg_2SiO4) microcrystallites in the initially non-stoichiometric smokes. After 4 hours annealing, forsterite and tridymite react to enstatite ($MgSiO_3$). We suggest that IR spectroscopy and X-ray diffraction analysis should be complemented by detailed AEM to detect budding crystallinity in vapor phase condensates.

97. Rietmeijer, Frans J. M.; Schramm, L. S.; Barrett, R. A. (Lockheed Engineering and Management Services Company); McKay, D. S.; and Zook, H. A. (JSC): The Main Electronics Box Thermal Blanket of the Solar Maximum Satellite as an Inadvertent Capture Cell for Orbital Debris and Micrometeorites. Presented at COSPAR XXVI, June 30 - July 12, 1986, Toulouse, France.

The physical properties of impact features in the Solar Max main electronics box thermal blanket are consistent with hypervelocity impacts of particles in the near-Earth space environment. The majority of particles are orbital debris and include spacecraft paint and bismuth-rich particles. At least 30% of all impact features are caused by micrometeorites which include silicates and sulfides. Some micrometeorites survive impact with only minor shock-metamorphic effects or chemical fractionation. Currently calibration experiments are under way to relate flux to particle diameter (or mass).

98. Schmidt, Robert M.; Wauchope, Charles R.; and Watson, Harris E. (Boeing Aerospace Company): Experimental Investigation of Crater Formation Dynamics. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 766-767.

99. Schramm, L. S.; Barrett, Ruth A.; Wentworth, S. J. (Lockheed Engineering and Management Services Company); Lieurance, M. L. (University of California-Los Angeles); and McKay, David S. (JSC): Particles Associated With Impact Features in the Main Electronics Box Thermal Blanket from the Solar Max Satellite. Presented at the 17th Lunar and Planetary

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Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 769-770.

100. Schramm, L. S. (Lockheed Engineering and Management Services Company); McKay, David S. (JSC): An Impact Crater Containing Meteoritic Material in a Louver From the Solar Max Satellite: A Comparison with Experimentally Produced Craters: Presented at the 49th Annual Meeting of the Meteoritical Society, September 22-25, 1986, New York, New York.

As part of a comprehensive SEM/EDXA (scanning electron microscopy/ energy dispersive x-ray analysis) study of Solar Max impact features, we examined and describe here a louver crater (sample 787) which contains abundant material thought to represent residue of a micrometeorite projectile. Many features found in crater 787 are similar to those produced by experimentally firing silicate projectiles of known chemistry into metal targets at velocities up to 6.4 km/s. These include: (a) abundant projectile material preserved in a nonuniform distribution as droplets, stringers, films, and masses; (b) surface relief of projectile melt varying from smooth to vesicular; and (c) metal spherules embedded in projectile melt, displaying immiscibility of metal target and silicate projectile melts.

101. Schramm, L. S.; Rietmeijer, Frans J. M.; Barrett, R. A. (Lockheed Engineering and Management Services Company); Blanford, G. E. (University of Houston - Clear Lake); and McKay, David S. (JSC): Classification and Identification of Particles in Impact Features on the Solar Max Satellite Main Electronics Box (MEB) Thermal Blanket. Presented at Cospar XXVI, June 30-July 12, 1986, Toulouse, France.

We analyzsed particles associated with impact features; i.e., those found on the front of the first layer within one crater or hole diameter and those in spray patterns on the front of the second layer of the Solar Max MEB thermal blanket. These particles, <1μm to -50μm in size, show spherical, globular, irregular, and fragmental morphologies. A higher proportion of contaminant particles on the front of layer 1 than on back of layer 1 and the front layer 2 probably contributes to the larger modal particle size on the front of the first layer. The chemistry of particles associated with impact features shows two distinctive and major categories: meteoritic particles and paint particles. The latter contains at least Ti, Si, or Zn as two of its major elements. Paint particles are concentrated on the front of layer 1, while meteoritic particles are largely found on the front of layer 2. The meteoritic particles include Mg- and Mg, Fe-silicates (MSF), Fe- and Fe, Ni-sulfides (FSN) and particles of approximate chondritic composition. MSF particles recovered from one impact feature are unshocked olivine (Fo77) single crystals (d(010) = 10.3A) that survived hypervelocity impact without melting. Our classification enables us to identify projectile residues but we recognize that the long duration exposure in space of the Solar Max satellite (50 months) may have resulted in superposition of meteoritic and paint particles associated with an impact feature.

102. See, Thomas H. (Lockheed Engineering and Management Services Company);

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Horz, Friedrich; and Morris, Richard V. (JSC): Apollo 16 Impact-Melt Splashes: Petrography and Major-Element Composition. <u>Journal of Geophysical Research</u>, Vol. 91, No. B13, pp. E3-E20, 1986.

Petrographic observations and major element analyses for 50 impact melt-splashes from the Apollo 16 landing site are presented. The objective was to evaluate whether they are melts derived from impacts into local soils or from local bedrock below the soil. The optical investigations indicate that most melt-splashes draped their host rocks inside the growing crater cavity; also, the specific host-rocks are the parent-materials of the impact melts. The observed host rocks represent a subset of all lithologies returned from the Cayley/Descartes landingsite and this limited suite of rocks is believed to characterize the Cayley formation in the southern half of the Apollo 16 landing site; most likely, the glasses and host-rocks are the ejecta of S-Ray Crater.

103. Shih, C. -Y.; Bansal, B. M.; Wiesmann, H. (Lockheed Engineering and Management Services Company); Dasch, Julius; and Nyquist, Laurence E. (JSC): Rb-Sr Chronology of Two High-K Mare Basalts Clasts from Breccia 14304. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 793-794.

104. Shih, C. -Y. (Lockheed Engineering and Management Services Company); Nyquist, L. E.; Bogard, D. D. (JSC); Bansal, B. M.; Wiesmann, H. Lockheed Engineering and Management Services Company); Johnson, P. (Northrop Services); and Taylor, L. A. (University of Tennessee): Geochronology and Petrogenesis of Apollo 14 Very High Potassium Mare Basalts. <u>Journal of Geophysical Research</u>, Vol. 91, No. B4, pp. D214-D228, March 30, 1986.

Rb-Sr, K-Ar, and Sm-Nd isotopic studies were undertaken for two Apollo 14 very high potassium (VHK) mare basaltic clasts from breccias 14305 and 14168. The samples are distinctly more radiogenic than other lunar mare basalts. Rb-Sr data for the whole rock and mineral separates determine internal isochrons corresponding to essentially identical ages of 3.83 ± 0.08 b.y. and 3.82 ± 0.12 b.y. Identical Rb-Sr and K-Ar isotopic results fro the two rocks indicate that they could be derived from the same flow. The source material for these basalts had a Rb/SR ratio similar to those of Apollo 14 high-Al mare basalts and a nearly chondritic Sm/Nd ratio. Extreme enrichments of Rb/Sr and K/La during the formation of VHK basalts can be adequately explained by an assimilation model that involves basalt/granite interaction. K, Rb-rich components of granitic wall rocks in highland crust were selectively introduced into ascending hot high-Al mare basaltic magma upon contact. A similar crustal assimilation process has been frequently observed in terrestrial, mantle-derived magma that ascended through the continental crust.

105. Simon, S. B.; Papike, J. J. (South Dakota School of Mines and Technology); Horz, Friedrich (JSC); See, Thomas H. (Lockheed Engineering and Management Services Company): Agglutinate Melting Mechanisms II: Shocked Lunar Soil Mixtures. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 803-804.

Agglutinates are extraterrestrial soil particles which consist of mineral, lithic, and glass fragments cemented together by a matrix of glass. The latter represents impact-fused soil. Papike proposed a model for agglutinate formation via fusion of the finest soil fraction (F^3) in which agglutinate glasses should exhibit chemical enrichments and depletions similar to those of the fine (<10 um) fines, which are fractionated from the bulk soil. In the first part of this study we shocked mixtures of albite and orthoclase and found that the compositions of the impact glasses were indeed more strongly influenced by the fine fraction than by the coarse fraction. Here we report the results of shock recovery experiments on soil mixtures, again with contrasting coarse and fine component compositions, but this time using actual lunar soils. The compositions of the impact glasses mimic those of the corresponding finest soil fractions and fall on a chemical mixing line between the bulk and the fine fraction.

106. Smith, John M. (Lockheed Enginering and Management Services Company); Meyer, Charles (JSC); Compston, W.; and Williams, I. S. (Australian National University): 73235,82 (Pomegranate): An Assemblage of Lunar Zircon with Unique Overgrowth. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science SVII, pp. 805-806.

Approximately 4310 My ago a relatively large (500+ micron) zircon crystallized within a clast of Ca-rich plagioclase. The zircon was fractured into numerous smaller crystals and was subsequently overgrown by a second generation of zircon at approximately 4183 My ago. The original bytownite clast was also shattered and regrown within this same time frame. Both zircon and bytownite were later emplaced within a melt sheet (breccia) around 4000 MY, without suffering any substantial lead loss or gain. Apparently neither the overgrowth event at 4180 MY nor the breccia formation at 4000 MY disturbed the U/Pb systematics of the zircon.

107. Smrekar, Suzanne (Southern Methodist University); Cintala, Mark J.; and Horz, Friedrich (JSC): Small-Scale Impacts into Rock: An Evaluation of the Effects of Target Temperature on Experimental Results. Geophysical Research Letters, Vol.13, pp. 745-748, August, 1986.

A series of cratering and catastrophic fragmentation experiments has been performed, involving the impact of aluminum and stainless-steel spheres into warm (~298K) and cold (~100K) granodiorite targets. Although some vague hints of a thermal effect might be found in some of the results, in no case was there a substantial difference between the warm and cold series. Since these experiments were well within the strength-dominated regime of impact phenomena, variations due to low target temperatures in more energetic events will probably be negligible. Thus, there appear to be no significant temperature-dependent mechanical effects during impact into solid rock over a wide range of temperatures prevalent in the solar system.

108. Sykes, M. V.; Hunten, D. M.; Low, F. J.; Lebofsky, L. A. (University of Arizona); McFadden, L. -A. (University of Maryland); and Vilas, Faith (JSC): A Survey of Solar System Dust Trails. Presented at the 18th Annual Meeting of the American Astronomical Society Division for Planetary Sciences, November 4-7, 1986, Paris, France.

Debris in the orbits of some periodic comets has been identified in the IRAS database. Viewed from the earth, many of these dust trails extend across several degrees to many tens of degrees of sky. Dynamical analysis of some of the cometary dust trails (associated with P/Tempel 2 and P/Gunn) indicates that a significant fraction of the dust trail material resides in millimeter through centimeter diameter particles, and that these trails are the superposition of cometary emissions over a few orbital periods. In order to identify all major dust trails at the time of the IRAS mission, we have begun an examination of the IRAS sky flux maps. Trails discovered are compared to the projected orbits of 136 short-period comets, 35 long-period and hyperbolic comets, 36 asteroids in comet-like orbits, and 58 meteor streams. The above comets and asteroids are also identified, where possible, to check for objects expected to have observable trails, but whose trails are not seen. Preliminary results of this survey are presented.

109. Sylvester, Paul J. (JSC); Attoh, Kodjo (Hope College); and Schulz, Klaus J. (U. S. Geological Survey): Did Anatexis in the Kapuskasing Structural Zone Produce the HREE-Depleted Dacites of the Michipicoten Greenstone Belt? Geological Association of Canada Annual Meeting, May 19-21, 1986, Otawa, Ontario.

Upper amphibolite to granulite facies migmatitic garnet-bearing mafic gneiss and paragneiss of the Kapuskasing structural zone are modeled geochemically as the residue of a partial melting event that produced the HREE-depleted dacites of the Michipicoten greenstone belt, Ontario. Modelled compositions of felsic melts derived from Kapuskasing mafic gneiss are most similar to Michipicoten HREE-depleted dacites after about 10% melting of a depleted basalt starting composition or approximately 50% melting of an enriched basalt, but anomalous concentrations of the LREE, Th, Co, and Ba suggest that a more complex model is involved. If compositions calculated for partial melts derived from Kapuskasing paragneiss are mixed with melts from the mafic gneiss, the composite model liquid possesses trace element (including LREE, Th, Co and Ba) abundances similar to the HREE-depleted dacites.

110. Sylvester, Paul (JSC); Attoh, Kodjo (Hope College); and Schulz, Klaus J. (U. S. Geological Survey): Melting of Mafic and Felsic Sources to Produce the HREE-depleted Dacites of the Michipicoten Belt, Ontario. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 859-860.

HREE-depleted dacites and tonalites, which comprise a significant component of the Earth's Archean sialic crust, are widely believed to have formed by 10-30% melting of mafic source rocks in the lower crust. In the Michipicoten greenstone belt of Ontario, however, trace element data are consistent with field and petrographic evidence that HREE-depleted dacites formed by anatexis of both mafic gneiss and paragneiss in the adjacent Kapuskasing uplift. Thus, models for growth rates of sialic crust during the Archean should not assume a simple sima to sial transformation always occurs, since significant reworking of existing sialic crust may also be involved.

111. Taff, L. G.; and Jonuskis, D. M. (Lincoln Laboratory, M.I.T.): Results

and Analysis of a Bi-Telescopic Survey for Low Altitude Orbital Debris. Presented at COSPAR XXVI, July 1986, Toulouse, France.

At the previous COSPAR meeting we reported on a unique bi-telescopic method of observing objects in near-Earth orbit. We also provided preliminary values for the ratio of the untracked to the tracked population of such objects (8:1). Since that time we have streamlined the video processing hardware, revisited the celestial mechanics analysis underlying the deduction of a particle's height - whether from a measurement of parallax or angular speed - and are increasing our observational program by a factor of ten. The bulk of this paper describes a now definitive statistical sampling of the 100-2000 km elevation range, presents height /inclination correlations, gives a complete number/height distribution curve, and so on. Unfortunately the early submission date of this abstract precludes the inclusion of meaningful results.

112. Thomas-Ver Ploeg, Kathie L.; and Rietmeijer, F. J. M. (Lockheed Engineering and Management Services Company): The Role of Alumina Polymorphs as Catalysts for Hydrocarbon Reactions in the Solar Nebula and Early Solar System. Presented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 893-894.

In a turbulent solar nebula, and early in the history of the solar system, the presence of metastable alumina polymorphs may have catalyzed hydrocarbon produced reactions.

113. Vilas, Faith (JSC): A CCD Search for Geosynchronous Debris. Icarus, Vol. 68, pp. 412-417, December 1986.

A search for objects in geosynchronous Earth orbit was conducted using the Spacewatch camera system. A total sky area of 8.78 sq deg was observed; some areas were covered on more than one night of observations. The telescope drive was off so that during the integrations the stars were trailed while geostationary objects appeared as round images. The technique should detect geostationary objects to a limiting apparent visual magnitude of 19. Ten objects were found, three of which were observed on separate nights. Seven of these objects are probably geostationary satellites having apparent visual magnitudes brighter than 14. Three objects having magnitudes fainter than 14 showed motion in the north-south direction. The absence of fainter stationary objects suggests that smaller debris does not exist in geostationary positions.

114. Vilas, Faith: Continued Studies of Outer-Belt Asteroids--New CCD Reflectance Spectra. Presented at the 17th Lunar and Planetary Science conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 913-914.

115. Vilas, Faith; Gaffey, M. J. (RPI); McFadden, L. A. (University of Maryland); and King, T. V. V. (U.S. Geological Sruvey): A Search for Weak Absorption Features in CCD Reflectance Spectra of Primitive Asteroids. Presented at the 18th Annual Meeting of the American Astronomical Society Division for Planetary Sciences, November 4-7, 1986, Paris, France.

Weak absorption features near 0.7 microns due to the presence of
iron oxides in phyllosilicates have been identified in terrestrial
serpentines and chlorites and carbonaceous chondritic material. Re-
flectance spectra acquired using a CCD spectrograph of C-, P-, D-, and
F-class asteroids (generally considered to be primitive solar system
material) are being examined for the presence of these absorption fea-
tures. For this study, these spectra were chosen from reflectance
spectra of 40 asteroids based upon criteria which included good spec-
tral signal-to-noise and photometric observing conditions. Median
filtering and FFT enhancement techniques are being conducted in order
to reduce noise and define any existing features. Possible sources of
spurious features, including variations among solar analog standard
stars and temporal changes in ozone absorption, are being simulated to
determine if they could cause absorption features. Preliminary exami-
nation indicates that some weak features exist among these spectra,
especially those of main-belt primitive asteroids. Results of the
more extensive study will be presented.

116. Vilas, Faith (JSC); and Mink, Douglas J. (Harvard-Smithsonian Center for
Astrophysics): JHK Photometry of Candidate Stars for Occultation by
Neptune. Publications of the Astronomical Society of the Pacific,
Vol. 98, pp. 116-117, January 1986.

JHK photometry is presented of six stars which will be occulted by
Neptune during 1986 and 1987. Two stars are possible candidates for
infrared photometric observations of occultations.

117. Wentworth, Susan J. (Lockheed Engineering and Management Services Com-
pany); and Gooding, James L. (JSC): Shergottite EETA79001: Petro-
logic Heterogeneity and Secondary Alteration in Lithology C. Pre-
sented at the 49th Annual Meeting of the Meteoritical Society,
September 22-25, 1986, New York, New York.

Seven new chips of Lithology C material from shergottite EETA79001
were studied by means of scanning electron microscopy and energy dis-
persive x-ray analysis. Lithology C is a term used for pockets of
impact glass in EETA79001; these pockets contain trapped gases that
suggest a Martian origin for the shergottites. Results of the study
showed that Lithology C is heterogenous with respect to both texture
and composition. Textures among the chips range from holohyaline to
almost entirely quench-crystallized. There is a wide range in glass
compositions within each chip and an even wider range from sample to
sample. Secondary phases (i. e., low-temperature aqueous alteration
products) are abundant in some samples; these include sialic rust and
secondary aluminosilicates as vein and vesicle fillings. Calcium car-
bonate is also present in two samples. It is not clear whether the
calcium carbonate is of Martian or Antarctic origin. A Martian origin
is possible, since the largest calcium carbonate deposit came from
near the center of the meteorite, away from the Antarctic weathering
environment; in addition, calcium carbonate has never been reported as
a product of weathering of Antarctic meteorites. Further work is
needed to constrain the origin of the secondary phases in EETA79001.

118. Wentworth, Susan J. (Lockheed Engineering and Management Services Com-
pany); and McKay, David S. (JSC): Grain Size and Petrographic Analy-
sis of Disaggregated Apollo 15 and 16 Regolith Breccias. Presented at

the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 937-938.

119. Whitehead, Victor S. (JSC); and Coulson, Kinsell (University of California at Davis): Optical Polarization Properties of Water Surfaces as Viewed from Orbital Altitude. Presented at the High Resolution Geophysics Symposium, NSTL, Mississippi, 1986.

   Polarized views of Earth have been collected by Space Shuttle crews using a pair of boresighted synchronized Hassleblad 70mm cameras onto which a vertical and a horizontal polarizing filter were attached. On STS 51-A more than 100 pairs of black and white images were acquired. Color pairs were acquired on STS 51-G, STS 51-I and STS 61-A (October 1985). Selected image pairs have been digitized, the vertical and horizontal polarized images registered to each other, and the image of the degree of polarization constructed, for several types of scenes and different sun-scene-observer geometries. Considerable difference in degree of polarization is apparent in many of the scenes. The degree of polarization varies significantly among colors for many scene components. Enhancement of patterns in some water surface features appear in the images of degree of polarization. Analysis of these images to determine information content relative to scene component discrimination, reduction of scene signal noise, atmospheric contribution, and water surface penetration is in progress.

120. Wood, Charles A.: Book Review of <u>Planet Earth</u>, by Jonathan Weiner. <u>Sky and Telescope</u>, Vol. 72, pp. 360-361, 1986.

121. Wood, Charles A.: Space Shuttle Observations of Volcanic Activity. Abstract published in <u>Environmental Effects of Volcanism Symposium Proceedings</u>, pp. 107-109, 1986.

122. Wood, Charles A.: Volcanoes: The Space Shuttle Legacy. Presented at the American Geophysical Union 1986 Fall Meeting, 1986, Washington, DC. Published in <u>EOS</u>, Vol. 67, p. 1073, 1986.

   During the first 24 Space Shuttle missions thousands of color photographs of volcanoes were taken by geologically trained astronauts using handheld cameras. Depending on the camera lens used the photos typically cover areas either 70 km or 170 km on a side, with resolutions of 30m or 80m - characteristics similar to Landsat TM and MSS images, respectively. Astronaut photos are taken at a variety of look angles, thus complementing the constant time and constant vertical view of Landsat images. The pictures are often excellent for reconnaissance studies of many of the world's volcanoes - the majority of which are unmapped - and have been used to plan field itineraries where maps are not available. In inaccessible or poorly mapped regions, the photographs provide basic statistical data on the existence, geometry, and morphology of volcanoes, thus facilitating volcano-tectonic interpretations. Digitization, rectification, and image processing of the photographs enhance analysis (e.g. measuring areas). Astronaut photos have also documented nearly three dozen eruptions, four of which were not otherwise reported.

123. Wood, Charles A.; and Amsbury, David: Salt Tectonics on Venus. Pre-

sented at the 17th Lunar and Planetary Science Conference, March 17-21, 1986, Houston, Texas. Abstract published in Lunar and Planetary Science XVII, pp. 954-955.

124. Wood, Charles A.; Francis, P.; and Bury, A.: 500 Volcanoes: A Census of Volcanism in the Central Andes. Abstracts of the International Volcanic Congress, p. 343, 1986.

125. Zolensky, Michael E., editor: Cosmic Dust Courier, Number 7. Lyndon B. Johnson Space Center, Houston Texas, 1986.

126. Zolensky, Michael E.: Tochilinite in C2 Carbonaceous Chondrites: A Comparison with Terrestrial Material. Presented at the 14th International Mineralogical Association Meeting, 1986, Palo Alto, California.

127. Zolensky, Michael E.; and Gooding, James L.: Aqueous Alteration on Carbonaceous-Chondrite Parent Bodies as Inferred From Weathering of Meteorites in Antarctica. Presented at 49th Annual Meeting of the Meteoritical Society, September 22-25, 1986, New York, New York. Published in Meteoritics, Vol. 21, pp. 548-549, 1986.

128. Zolensky, Michael E. (JSC); and MacKinnon, Ian D. R. (University of New Mexico): The Microstructures of Cylindrical Tochilinites. The American Mineralogist, Vol. 71, pp. 1201-1209, 1986.

Individual tochilinite (ideally $2Fe_{0.9}S$ $1.67[(Mg, Fe) (OH)_2]$) fibers from Cornwall, Pennsylvania, and the Jacupiranga Mine, Brazil, have been examined using scanning electron microscopy (SEM), analytical electron microscopy (AEM), and high resolution transmission electron microscopy (HRTEM). Dominant morphologies for tochilinite from these locations are filled and hollow cylinders. HRTEM of Cornwall tochilinite cylinders reveals that they are composed of laths stacked into polygonal sectors around the cylinder axis. Within each polygonal section the curvature of the tochilinite sheets does not exceed 10^{-2} radian. Adjacent laths are slightly rotated about the cylinder axis, which provides the effective curvature responsible for the cylindrical morphology. Greater effective sheet curvature results in cylinders, as shown by the material from Cornwall. Tochilinite from the Jacupiranga Mine has a smaller effective sheet curvature, which results in a cladded morphology. Similar morphologies can be observed for the "poorly characterized phases" within C2 carbonaceous chondrite meteorite matrices.

129. Zolensky, Michael E.; McKay, David S. (JSC); Schramm, L. S.; Thomas-Ver Ploeg, K. L. (Northrop Services); Warren, J. L.; Watts, L. (Lockheed Engineering and Management Services Corporation), compilers: Cosmic Dust Catalog, Vol. 8/No. 1: Particles from Collection Flag W7013. Lyndon B. Johnson Space Center, Houston, Texas, November, 1986.

This catalog summarizes preliminary observations on 123 particles retrieved from collection surface W701, a silcone-oil-coated flat plate "flag" (with a 30 cm^2 surface area) which was flown aboard a NASA WB57-F aircraft over west-central North America from May through July 1981. This flag was installed in a specially constructed wing pylon which ensured that the neccessary level of cleanliness was maintained between periods of active sampling. During successive periods

of high altitude (20 km) cruise, the flag was exposed in the stratosphere by pilot command and then retracted into sealed storage containers prior to descent. A total of 65 hours of stratospheric exposure was accumulated for flag W7013.

130. Zolensky, Michael E. (JSC); and Pace, James G. (Michigan Technical Institute): Alteration of Tephra in Glacial Ice by Unfrozen Water. Presented at the 99th Annual Geological Society of America Meeting, November 10-13, 1986, San Antonio, Texas.

Tephra-rich samples of blue ice were gathered from the Far Western Ice Field and the Allan Hills Main Ice Field in South Victoria Land, Antarctica. These ice sheets have been dated at $<1.2x10^5$ and 3 to $6x10^5$ years old respectively. Tephra from the Far Western Ice Field was fine-grained (10μm mean), containing abundant basanitic glass and phenocysts of forsterite (Fo79), bytownite (An73), fassaite, and sulfides. By comparison, the tephra from the Allan Hills Main Ice Field was ten times as coarse-grained and contained less glass, with phenocrysts of kaersutite, forsterite (Fo85), plagioclase (variable), cpx (Wo50 En27), sulfides, and oxides. Despite the fact that this tephra has lain encased in snow and ice since immediately after its deposition, aqueous alteration products are ubiquitous. When ice exists in intimate contact with solids a thin interfacial layer of so called "unfrozen water" is present, allowing ionic migration and consequent aqueous alteration to occur at temperatures even below -10°C. Alteration due to the action of "unfrozen water" will disturb analyses of otherwise pristine Antarctic tephra, complicating tephra chronology studies. Surficial alteration of glass grains to imogolite will serve to substantially increase the apparent bulk abundance of alumina and water, at the expense of all other components.

131. Zook, Herbert A.: Composition of Comet Halley Dust Particles from Giotto Observations. <u>Nature</u>, Vol. 321, pp. 336-337, May, 1986.

Mass spectra of cometary dust particles measured by the PIA instrument onboard Giotto show quite some unexpected and striking features. Small particles below 10^{-14} g are much more abundant than anticipated by the models. Most of the particles are rich in light elements such as H, C, N, and O, suggest to the validity of models describing the cometary material as including organic material. The light elements specifically seem to have a low ratio of mass per volume. Three examples of original mass spectra showing typical compositions are compared to a synthetic (computer generated) mass spectrum which shows what had been expected.

132. Zook, Herbert A.: On the Asteroidal Component of Cosmic Dust. Abstract published in <u>Lunar and Planetary Science XVII</u>, pp. 977-978, 1986.

133. Zook, Herbert A.: Precision Requirements on Cosmic Dust Trajectory Measurements. In Horz, Friedrich, editor: Trajectory Determinations and Collection of Micrometeoroids on the Space Station. LPI Technical Report 86-05, pp. 97-99, Lunar and Planetary Institute, Houston, Texas, 1986.

Man-Systems Division

1. Britell, Catherine (VA Medical Center); Ciciora, John; Johnson, Dale
   (Johnson Engineering Corporation); and Louviere, Laura L. (JSC): The
   Unistik Vehicle Controller: A Unique Approach to Driving for People
   with Disabilities. Presented at the 12th Canadian Medical and Bio-
   logical Engineering Conference, 1986, Vancouver, Canada.

   The Unistik (TM) represents a unique, cost-effective, and reliable
   system for enabling people with severe physical disabilities to drive
   a motor vehicle. It is wholly contained within the passenger compart-
   ment, is easily installed, and retains the integrity of the normal ve-
   hicle control system. Since the device is a "bolt-on" system, it can
   be moved to a new vehicle with ease and is expected to last the life-
   time of the user. The expected relative low cost and wide availabil-
   ity of the system will make driving available to a significant number
   of people who would otherwise be dependent in transportation.

2. Gillan, Douglas J.; Burns, Michael J; Nicodemus, Clarence L.; and Smith,
   Randy L. (Lockheed Engineering and Management Services Company): The
   Space Station: Human Factors and Productivity. Human Factors Society
   Bulletin, November, 1986.

   This paper describes research and development at NASA for increasing
   the productivity of crews on the Space Station in intravehicular (IV)
   workstations, extravehicular (EV) workstations, and telerobotics. Re-
   search on IV productivity has centered around the physical character-
   istics of workstation design, human-computer interactions, and the
   construction and use of expert systems. The focus of EV productivity
   has been on the interface between the human and various devices, in-
   cluding the extravehicular mobility unit (EMU), manned maneuvering
   unit (MMU), and work tools. Telerobotics on Space Station will in-
   volve an IV crewmember operating an EV robot; research and development
   issues for space telerobotics include the information required by the
   operator and the flexible allocation of tasks to the operator and ro-
   bot as a function of increasing autonomous capabilities in the robot.

3. Lewis, Ruthan (Lockheed Engineering and Management Services Company):
   Human Factors Design Criteria for Spaceflight Intravehicular Crew Re-
   straints. Presented at the Human Factors Society 30th Annual Meeting,
   September 29-October 3, 1986, Dayton, Ohio. Published in Proceedings.

   Proper design of devices to restrain and position astronauts in mi-
   crogravity is essential for working and living in space. This paper
   traces the development of crew restraints throughout the history of
   the U.S. space program and examines the functioning of various re-
   straints in their conditions of use. Design issues and recommended
   design guidelines for intravehicular crew restraints are identified.

4. Miller, Keith H. (Boeing Aerospace Company): Man/System Integration
   Standards for Space Systems. Presented at the Human Factors Society
   Annual Meeting, September 29-October 3, 1986, Dayton, Ohio.

   This paper presents an overview of the Man/System Integration Stan-
   dards (MSIS) program standards to be developed to ensure proper inte-
   gration of the man/system interface requirements for launch, reentry,
   on-orbit, and extraterrestrial space environments with those of other

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aerospace disciplines. Concise design considerations, design require-
ments, and design examples are provided. The standards are being
developed through a Government/ Industry Advisory Group (GIAG). The
documentation will consist of four hard copy volumes, a videotape, and
a relational database. The videotape uses in-space film footage from
Gemini, Skylab, and the Shuttle to illustrate specific man/system
integration problems (scenes are cross-referenced to the MSIS topics).
The relational database provides a means for storing and manipulating
the MSIS data.

5. Regal, David M. (Lockheed Missiles and Space Company): Human Perform-
      ance in Space. Presented at the Human Factors Society Annual Meeting,
      September 29-October 3, 1986, Dayton, Ohio.
      This paper describes some of the ways in which human capabilities in
   space are different from those on Earth, including visual and auditory
   perception, olfaction and taste, kinesthesia, coordination, and ves-
   tibular function. Workload considerations are presented, and psycho-
   logical and social factors that can affect crew performance on long-
   duration space missions are discussed.

6. Stramler, James H. (Northrop Services): A Comparison Between Space
      Suited and Unsuited Reach Envelopes. Presented at the Human Factors
      Society Annual Meeting, September 29-October 3, 1986, Dayton, Ohio.
      A comparison was made for the reach capability of Shuttle space suit
   vs. unsuited. Graphics were generated and reach envelope volumes com-
   puted. The space suit reduces the reach envelope volume from about
   64% to 97%, depending on the type of envelope measured.

7. Thurmond, Beverly A.: Space Station Food System Development. Presented
      at the R and D Associates for Military Food and Packaging Systems,
      Inc., 40th Annual Meeting, April 1-4, 1986, Orlando, Florida.
      Published in Proceedings, Vol. 38, No. 2, pp. 10-11.
      Currently three advanced development study projects are being con-
   ducted for NASA in the areas of the food supply and service system,
   the advanced food hardware system, and the personal hygiene system.
   The studies are related through the sharing of data base systems and
   joint working group meetings. These studies are two year projects
   which will result in requirements definitions, end-item system speci-
   fications, and identification of areas requiring further research and
   development efforts. Study results will be incorporated into Space
   Station efforts as information becomes available.

8. Thurmond, Beverly A. (JSC); Gillan, Douglas J. (Lockheed Engineering and
      Management Service Company); Marcus, B. (Arthur D. Little); and
      Bourland, Charles T. (Technology, Incorporated): Space Station Food
      System. Presented at the 16th Intersociety Conference on Environ-
      mental Systems, July 14-16, 1986, San Diego, California.
      A team approach including members from NASA, aerospace companies,
   and the food industry was taken to study current and advanced tech-
   nologies in food related areas to develop requirements and specifi-
   cations for the Space Station food system. Food system interfaces
   with power, water, and contamination control systems were taken into
   consideration, but optimization of the human interface with the food
   system remained the most important criterion due to habitability con-

cerns. Areas addressed by trade-off studies to determine feasible concepts included daily food, emergency food, extravehicular activity food, packaging, storage, utensils, ground operations, serving techniques, resupply logistics, trash management, sanitation, contamination control, maintenance and quality control. Results of the study will determine end-item specifications for the Space Station food system and identify areas requiring further research and development efforts.

9. Thurmond, Beverly A. (JSC); Gillan, Douglas J.; Perchonok, M. H.; Goodman, A. H. (Lockheed Engineering and Management Services Company); Marcus, B. (ADL); and Bourland, C.T. (Technology, Incorporated): Space Station Food System Development. Presented at the Institute of Food Technologists Annual Meeting, June 15-18, 1986, Dallas, Texas.

A preliminary food system was designed for the NASA Space Station which will be launched in the early 1990's. A unique multi-disciplined approach was used in conjunction with a data management system and trade-off analyses to arrive at a food system which includes freezers, refrigerators, microwave ovens, convection ovens that reach 350°F and controlled atmosphere storage of fruits and vegetables. One of the design goals of the food system was to make it as Earth-like as possible. An industrial advisory board made up of volunteers from various segments of the food industry provided guidance and direction.

10. Tillman, Barry (Lockheed Missiles and Space Company): Human Factors Standards for Space Habitation. Presented at the Human Factors Society Annual Meeting, September 29-October 3, 1986, Dayton, Ohio.

NASA is developing a Man/System Integration Standard for the design and development of space habitats. Included in this paper is a discussion of the anthropometrics, architecture, activity centers, and health management sections of the standard. There is a brief description of the general contents of each of these sections and some of the human factors considerations that are unique to the space environment.

11. Trabanino, Rudy (JSC); Yakut, Mahmoud; and Murphy, George (McDonnell Douglas Astronautics Company): Space Station Galley Design. Presented at the 16th Intersociety Conference on Environmental Systems, July 14-16, 1986, San Diego, California.

This paper summarizes requirements, design concepts, and baseline configuration for an advanced food hardware system (AFHS) for the Space Station. It is planned that Space Station will employ unique food hardware items that have never been flown in space such as a dishwasher, microwave oven, blender/mixer, bulk food and beverage dispensers, automated food inventory management, a trash compactor, and an advanced technology refrigerator/freezer. Each of these new technologies and designs is described and the trades, design, development, and testing associated with each are summarized. Space Station objectives and constraints which impact the design of food hardhardware and their implications for hardware selection, design, and test are described.

12. Woolford, Barbara (JSC): Manned Space Flight. Presented at the Human Factors Society Annual Meeting, September 29-October 3, 1986, Dayton, Ohio.

An overview of manned space flight is given. This describes the key goals and achievements of the space programs of the United States and of the Soviet Union. The importance of the "Man" in manned space flight is emphasized. Human factors are shown to have played an ever increasing role in the design of manned spacecraft.

13. Zlatkis, Albert (Ionics Research): Organics in Water Contamination Analyzer - Phase I. NASA CR-179901, June 1986, 14 p.

A study was undertaken to identify the components of an automatic system for analysis of specific organic compounds in the Space Station potable water supply. The gas chromatographic system for such an analysis is limited to commercially available off-the-shelf hardware and includes the sample inlet, an ionization detector, and capillary columns as well as computerized compound identification. The sampling system will be a special variation of the purge and trap Tenax mode using six-port valves and a 500 microliter water sample. Capillary columns used for the separating of contaminants will be bonded phase fused silica with a silicone stationary phase. Two detectors can be used: photoionization and far ultraviolet, since they are sensitive and compatible with capillary columns. A computer system evaluation and program with the principle of compound identification based on the retention index is presented.

Artificial Intelligence and Information Sciences Office

1. Crouse, Kenneth R.; Spitzer, J. F. (Mitre Corporation): Design Knowledge Bases for the Space Station. Presented at ROBEX 86, June 3-4, 1986, Houston, Texas.

    The Space Station will require a high degree of system autonomy to function efficiently over its lifetime. Autonomous operation necessitates that systems be maintained and repaired using knowledge-based expert systems and robotics. Knowledge of the geometry of systems, functionality, procedures, rationale for design decisions, relationships among components, must be captured during Space Station design by the contractors using readily available hardware and software with minimal impact on the design process. Appropriate choices of software tools and techniques of knowledge representation are required for successful design knowledge capture.

2. Heydorn, Richard P.: Managing Design Convergence of Automation and Robotics for NASA's Space Station: A Mathematical Look. Invited lecture at the University of Houston, March 5, 1986, Houston, Texas.

    Conceptual designs of NASA's Space Station make use of telerobots, robots, expert systems, intelligent graphics, and other modern automation approaches to assembly and operation. These designs offer a number of options which must be compared against many competing criteria related to variables such as cost, safety, reliability, spinoff potential, etc. The process by which a large number of possible design options are reduced to a single design has been called design convergence. To aid in the management of this process, NASA is using multiattribute decision analysis and economic network models. This talk covers some of the mathematical properties of these models and illustrates their application to design convergence.

3. Wechsler, Donald B. (Mitre Corporation); and Crouse, Kenneth R. (JSC): A Framework for Design Knowledge Capture. Presented at the SPIE International Conference on Space Station Automation II, October 26-31, 1986, Cambridge, Massachusetts.

    Design of NASA's Space Station has begun. During the design cycle, and after activation of the Space Station, the recurring need will exist to access not only designs, but also deeper knowledge about the designs, which is only hinted at in the design definition. Areas benefiting from this knowledge include training, fault management, and onboard automation. NASA's Artificial Intelligence Office at Johnson Space Center and the Mitre corporation have conceptualized an approach for capture and storage of design knowledge.

STS INTEGRATION AND OPERATIONS OFFICE

1. Bickel, Michael Allen (Mitre Corporation): Automatic Correction
   to Misspelled Names: A 4th Generation Language Approach. Communi-
   cations of the ACM, Vol. 30, No. 3, pp. 224-228, March 1987.
   NASA has a data base for tracking tasks which uses personal names
   as part of the key and must ensure that these names are spelled con-
   sistently. A table of valid names is specified in a schema declar-
   ation using NOMAD2, with the requirement that each name entered into
   the data base be a member of this names table. On membership failure,
   this application reads the user's screen for the misspelled name and
   then searches for the nearest valid name in the names table. Each
   letter is assigned a number from 3 to 9 as an information weight; 3 is
   the weight for "a,e,i,n,o,s,t"; 4 is the weight for "d,h,l,r,u"; 5 is
   the weight for "c,f,g,m,p,w"; 6 is the weight for "b,v"; 7 is the
   weight for "k,q"; 8 is the weight for "j,x,y"; 9 is the weight for
   "z". The weight assigned to a letter is based upon the relative fre-
   quency with which that letter occurs in the names table. This algo-
   rithm computes a likeness value for any pair of names as follows: the
   likeness is initially set to zero; then, for each letter in the alpha-
   bet, if that letter is present in both names, the weight for that let-
   ter is added to the likeness value. Pairing the misspelled name with
   each name in the names table, a likeness value is computed for each
   pair. From the pair with the largest likeness value, the name most
   probably intended by the user is displayed.

2. Chassay, Charles E.: A Monograph of the National Space Transportation
   System Office (NSTSO) Integration Activities Conducted at the NASA
   Lyndon B. Johnson Space Center for the EASE/ACCESS Payload Flown on
   STS 61-B. Presented at the Space Construction Conference, August 6-7,
   1986, Hampton, Virginia.
   The integration process of activities conducted for the experimen-
   tal assembly of structures in extravehicular activity (EASE)/ assembly
   concept for construction of erectable space structures (ACCESS) pay-
   load is provided as a subset to the standard payload integration pro-
   cess used to fly payloads on the Space Shuttle. The EASE/ACCESS pay-
   load integration activities are chronologically reviewed in this paper
   beginning with the initiation of the flight manifesting and integra-
   tion process. The development and documentation of the EASE/ACCESS
   integration requirements are also discussed along with the implemen-
   tation of the mission integration activities and the engineering as-
   sessments supporting the flight integration process. In addition, the
   STS management support organizations, the payload safety process lead-
   ing to the STS 61-B flight certification, and the overall EASE/ACCESS
   integration schedule are presented.

3. DeAtkine, David D. (JSC): The Space Shuttle Standard Launch Window.
   Presented at the SAE 1986 Aerospace Technology Conference, October 13-
   16, 1986, Long Beach, California.
   To maximize the efficiency of the Space Transportation System as a
   shared cargo launch system and to enhance the mixability and launch
   opportunities for payloads carried on the Space Shuttle, NASA has

developed a shared cargo standard launch window. The launch window is based on the transfer orbit Sun angle requirements of an established, common class of geosynchronous communications satellites. It is applicable to mixed cargoes launched from the John F. Kennedy Space Center into 28.5° inclination orbits. The window consists of two time periods, each 2 hours long, centered at 0023 and 1223 Greenwich mean time, and extends unchanged throughout the year.

STS ORBITER AND GFE PROJECTS OFFICE

1. Goodman, Jerry R.: Recent Shuttle-Orbiter Crew Compartment Design Improvements. Presented at the 30th Annual Meeting of the Human Factors Society, September 29 - October 3, 1986, Dayton, Ohio.

   Significant design improvements to the Shuttle waste management system (WMS) and its related personal hygiene support provisions (PHSP) have recently been made to improve overall operational performance and human factors interfaces. The WMS design improvements basically involve improved urinal flow and processing, individual urinals, and provisions for manually compacting feces and cleanup materials to ensure adequate mission capacity for worst case missions. The basic arrangement and stowage of the PHSP used during waste management operations were extensively changed to better serve habitability concerns and operations needs and to improve the hygiene of WCS operations. This paper describes these changes, and the design/ development and flight test evaluation of these improvements. In addition, other unique mission dictated or improvement type changes are described, such as additional provisions for eight crewmembers and changes to a new four-tier sleep station.

2. Kalthoff, Clem H.; Bradshaw, R. L.; Bartkus, E. A.; and Finkelstein, B. I. (IBM): Magnetic Tape Recovery and Rerecording of Data. Presented at the Magnetism and Magnetic Materials Conference, November 17-20, 1986, Baltimore, Maryland.

   Degraded magnetic tapes and data were recovered from damaged reels through a series of chemical, mechanical, and rerecording processes. This paper describes the procedures used on three reels of tape recovered from the Space Shuttle Challenger after being immersed in the ocean for six weeks.

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